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THE UNIVERSITY OF ALBERTA

Word Recognition, Memory Span in Chinese-English Bilingual Readers

by

Becky Lau Po-Lin

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND

RESEARCH IN PARTIAL FULFILMENT OF THE

REQUIREMENTS FOR THE DEGREE

OF Master of Education
IN
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Department of Educational Psychology

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FALL, 1988

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ABSTRACT

The purpose of this study was to investigate the relationship among rapid, automatic recognition of word, memory span, and reading comprehension in Chinese-English bilinguals. In order to achieve the goal, the performance on word recognition tasks and memory span tasks of 15 balanced and non-balanced bilinguals was examined. The word recognition tasks consisted of a physical-matching task and a name-matching task whereas the memory span tasks consisted of a visual and an auditory mode of presentation.

The results of the experiment showed that language has an effect on performance. Performance in Chinese word recognition was faster and more accurate than in English except in the case of English name matching. Performance in memory span tasks was consistently to be better in Chinese than in English. The present results suggest that memory span and word processing speed are affected by language characteristics. Moreover, non-balanced bilinguals showed a greater effeciency in using Chinese over English in the auditory memory span task. It supports the idea that language proficiency is an important source of individual differences in working memory.

In addition to the above findings, the correlation between word recognition speed and reading comprehension indicates that processing speed is a crucial source of individual variation in comprehension. A further source of variability in reading

comprehension appears to be memory span, which correlates positively with reading comprehension. These two findings are true for both Chinese and English. The results of the present study therefore were in line with previous studies indicating an important relationship between word recognition efficiency, memory span and reading comprehension.

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Chapter 1

Introduction and Review of Literature

1.1 Introduction

Teaching children to read is one of the prime goals of schooling. Learning how to read seems to be an easy matter for some children, whereas for others it is a problem. Similarly, adults vary in their ability to read with comprehension. Over the past decade there has been a dramatic increase in the amount of both theoretical and experimental work devoted to the topic of reading comprehension. While there are controversies and issues awaiting to be resolved, some general patterns of individual variation in reading ability have been revealed.

Many models of reading have been proposed to explain the reading process. One of these perspectives is cognitive information processing and in particular the role of working memory. The role of working memory capacity has been intensively investigated (Deneman and Carpenter, 1980). According to Baddeley and Hitch (1974), working memory has both processing and storage functions that compete for a limited capacity. This trade-off between processing and storage activities has been used to explain differences in reading achievement (e.g. Torgesen 1979; Torgesen and Houck, 1980). The general conclusion reached is that working memory capacity accounts for many of the individual differences in reading achievement.

Several current models of reading ability discuss it in terms

of the processes involved (e.g. LaBerge and Samual,1974; Perfetti and Lesgold, 1977). Different reading models view the flow of information processing from different perspectives. However, common to almost all of these models is the emphasis on word recognition. A number of studies (e.g. Stanovich, 1982) have shown that word recognition is a significant contributor to variability in reading.

On both theoretical and empirical grounds there are reason and evidence to support the notion that memory span capacity, and word recognition are crucial components of reading in English. However, are such relationships universal across languages? Do similar relationships exist between memory span capacity, word recognition and reading ability in reading a different writing system, such as the Chinese writing system? This study is an attempt to answer these questions. Bilinguals have often been the subject of research into cognitive processes. One reason is that some aspects of a specific skill may be relatively weaker in one of the speaker's languages. In this case, a bilingual presents an opportunity to compare skilled and less skilled performance in the same individual. Such a comparision may provide an opportunity to study the speed of word recognition and memory span capacity in different language systems and in different levels of proficiency. If bilingual readers exhibit a relationship between word recognition, memory span capacity and reading comprehension in two languages such as Chinese and English, then one might come closer to answering whether

reading involves universally-similar cognitive activities.

1.2 Review of Related Literature

The following review of related literature will focus on some of the variables that are related to reading comprehension. It begins with a review of working memory models and empirical evidence with reference to reading comprehension. Since the present study is an attempt to determine whether a relationship exists between word recognition and reading comprehension in the two different languages of Chinese-English bilingual readers, it is necessary to discuss issues in bilingual memory and relevant literature in the reading of Chinese and English. The controversial issue of separate and common memory store will be discussed and then followed by a review of theory and research in the reading of English and Chinese.

1.2.1. The Working Memory Model

Within the information processing model, the issue of whether or not differences in working memory capacity can affect reading achievement has been intensively explored. The working memory model proposed by Baddeley and Hitch (1974) conceptualizes working memory as a highly active part of the human information processing system. According to these authors, working memory is a limited capacity system comprised of both processing and storage functions which has a span-like quality. The system is made up of three parts; a central executive

component, an articulatory loop and a visuo-spatial "scratch pad". Activities of the central executive component include the setting up of appropriate rehearsal routines such as the loading up of the articulatory loop and the retrieval of information from a buffer when necessary. Information is processed in the central executive and it is transformed into a speech-like code. It is then stored in this speech-like form in a buffer until recall is required. The articulatory loop is relatively passive and makes few demands on the central executive component as long as it is operating within its limits. If the capacity of the articulatory loop is exceeded, the central executive component may become involved in storage activities so that proper maintenance of this information can take place. Information in the buffer may be subject to loss if this is not executed.

The articulatory loop is one of the "slave" systems that help the central executive component in processing speech-based materials. This system is regarded as responsible for the many speech-like characteristics of short-term memory and is concerned with maintaining speech information through subvocalization.

The visuo-spatial "scratch pad" is regarded as a temporary spatial memory system. The system relies on spatial rather than visual coding.

Baddeley and Hitch (1974,1977) hypothesize that part of the working memory system consists of a general purpose work space. They suggest that the limited capacity of the work space could be

flexibly distributed between the two functions of processing and storing information, according to task demands. Thus, there is a trade-off between the amount of work space devoted to these two functions.

Since both processing and storage functions share the same limited capacity, the speed of processing has an effect on the storage functions. If processing is executed rapidly, then more capacity is left for storage and maintenance of the products of processing. However, a slower speed of processing would result in few resources left over for storage and maintenance of processed information.

Memory span has often been used as a measure of working memory capacity. While decomposing the memory span task, two component processes have been implicated in task performance----item identification and memory for the order in which items occur. Item identification reflects the speed of accessing the names for presented items from long-term memory and has been recognized as an important component of memory span (Dempster,1981). Item order requires a successive processing of the stimulus items (Das,1984). The speed with which items are identified has been proposed as a variable which underlies memory span performance (Case & Goldberg,1981). The assumption is that there are major differences between individuals in the ease with which appropriate perceptual-cognitive units and the appropriate linguistic programs are activated (Dempster, 1981). Differences in difficulty are reflected in the capacity

necessary for the identification process. In other words, these are reflected in the degree of automaticity in the identification process. An individual who experiences difficulty identifying items will have relatively less capacity remaining for storing items and thus will have a shorter memory span than someone who identifies items with ease. Some proponents of this hypothesis suggest that ease of item identification is directly related to speed of item identification (Case, Kurland and Goldberg, 1981; Chi, 1977; Huttenlocher and Burke, 1976). The speed of item identification is taken as an indicator of the automaticity of the identification process.

Item order has been proposed as another component influencing memory span. This possibility has been suggested by several researchers (e.g. Estes, 1974; Huttenlocher and Burke, 1976) specifically to account for a portion of the increase in span during childhood. However, this proposition has not been tested extensively (Dempster, 1981; Gajraj, 1983).

In brief, Baddeley and Hitch (1974, 1977) have proposed a single working memory system operating for verbal reasoning, prose comprehension and free-recall learning, and it has a span-like quality. The working memory system is a limited capacity system which consists of processing and storage functions. Information is presented in the central executive where it is transformed into a speech-like code and then stored in the articulatory loop until recall. If processing is executed rapidly, then more capacity is left for storage and maintenance of the processed

products. Given this model, the speed of processing information is hypothesized to be a determinant of memory span performance.

1.2.2 Empirical evidence supporting the working memory model

Support for the working memory model comes from a group of studies. Conrad and Hull (1964) and Hintzman (1969) found that if a subject is required to repeat a sequence of consonants or words, then the more similar in sound or articulation the items comprising the sequence are, the greater the probability of error. Conrad (1972) also found this phonological similarity effect in children. These studies support the idea that memory codes used to store information in working memory are made up of phonetic features of the stimuli to be recalled. That is, incoming stimuli are coded in terms of their critical acoustic or phonetic features.

Baddeley, Thomson and Buchanan (1975) reported that memory span for words is a simple function of their spoken duration. They found that the crucial variable is spoken duration rather than the number of syllables. Thus disyllabic words with long vowel sounds are less well recalled in a memory span situation than words that have short rapidly-spoken vowels. In addition, they also found that if subjects are prevented from subvocally rehearsing material by requiring them to utter some irrelevant speech sound , then their immediate memory span is impaired. This is referred to as the articulatory suppression effect.

Colle & Welsch (1976) and Salame & Baddeley (1982) found

an unattended speech effect. If subjects are required to remember a sequence of visually presented items, then their performance will be markedly impaired if irrelevant material is spoken at the same time.

Baddeley & Hitch (1974) base this working memory model solely on data obtained from monolingual subjects. However, the memory of bilingual persons may be different from that of monolinguals since more than one language is present in their repertoire. Bilingual individuals have to process more than one language in regard to input and output modes in their daily lives. How bilinguals process information in their memory has been the subject of study for psychologists. The next section is concerned with the controversial separate and common store views of bilingual memory.

1.2.3. Bilingual Memory

A large proportion of the information-processing research related to bilingualism has been concerned with memory and learning. Do bilinguals store items as concepts independently of the language of input, or as language-specific units? As in many similar cases in which problems are formulated in an extreme manner, a 'commonsense'- hypothesis would predict something in between the two extreme assumptions. One should expect that both language-free storage and language specific storage take place according to the task demands.

Some investigators (e.g. Altenberg, 1983; Tulving and

Colotala, 1970; Paivio, 1981) have suggested that bilingual memory may be represented by two functionally independent storage and retrieval systems, one for each language. This separate-storage hypothesis assumes that items are stored in one or the other depending on the language of input. In a memory task such as a successively presented list of unrelated verbal items, translation equivalents would behave as new items and would not affect the retention of the old ones. There would neither be any positive or negative transfer, nor retroactive or proactive interference.

On the contrary, some investigators (Kintsch,1970; Lopez & Young,1974; MacCormack,1977; Potter Eckardt & Feldman, 1984) have suggested that bilingual memory may be represented in one single memory store. This common store hypothesis assumes that items are stored in the bilingual's memory in the form of language-free concepts, regardless of the language of input. Translation equivalents behave as old items, and transfer, inhibition and interference would occur interlingually.

Both the separate and common-store hypotheses have received supporting evidence. Several studies (e.g. Kolers,1963: Goggin and Wickens,1971; Paivio,1981) have provided support for the separate store hypothesis. Kolers (1963) using a word association test found that material encoded in one language was not necessarily available in the other language. He noticed that subjects gave different associations to equivalent words in different languages. It is suggested that bilinguals have separate encoding

routines and storage systems for experiences represented in the two languages.

Goggin and Wickens (1971) employed English-Spanish bilingual subjects who were given three consecutive tests for short-term retention of words in either English or Spanish. Proactive interference was evident in the deterioration of performance across tests. However, on the fourth test, the experimental groups were shifted to items from the other language. They found a release from proactive interference and an overall recovery of 68% when language was changed. This finding suggested that the data could be interpreted as support for separate memory stores for each language.

Tulving and Colotla (1970) in their study using single trial free-recall with unrelated words found that recall performance was highest on items from unilingual lists, intermediate on items from bilingual lists, and lowest on items from trilingual lists. These results suggest that subjective organization of words becomes more difficult across language boundaries. The structure of the multilingual lists interfered with the subject's ability to organize. In other words, organizational processes are restricted to the formation of higher order retrieval units made up of items in only one or the other language. Organization of words seems not to generalize to the other language interlingually.

Scarborough, Gerard & Cortese (1984) tested Spanish-English bilinguals in two lexical decision, word recognition experiments. In one experiment, practice on words

from one language facilitated later recognition of translations of those words. In a second experiment, subjects were told to respond differently to words of two languages. Results indicated that bilinguals in a word recognition task are able to process the words of a language in a language-specific manner. This study indicates some degree of language specificity in bilingual memory.

Paivio and Lambert (1981) conducted two experiments to compare the effects of verbal-nonverbal and bilingual dual coding on recall. The first experiment required French-English bilinguals to code a mixed list of pictures, French words, and English words by writing the English names of the pictures, translating the French words, and copying the English words. The second experiment reversed the coding task in that bilinguals were presented with only English words along with coding cues that prompted them to sketch the referents of one-third of the items, translate another third into French, and copy a third. Free recall tasks were given at the end of the experiments. Both experiments revealed that item recall increased significantly from the unilingual to the bilingual lists which provides support for a version of the independent or separate stores view of bilingual memory.

In a more recent study by Watkins and Peyniricioglu (1983) subjects were presented with mixed lists of English and Spanish words who then tried to complete fragments of the presented words, of translations of presented words, and of entirely new words. Results suggested that recall of individual words from a

study list of a particular language is more appropriately considered as being directly connected to words of that language, rather than as mediated by the concepts that they represent. The separate store view of bilingual memory was again supported.

Bilingual memory research has also given support to the common-store hypothesis. Kolers (1966) was the first to demonstrate the 'bilingual equivalence effect' (i.e., that translation equivalents behave as old items) in short-term memory. French-English bilinguals were given a word list in one language and its translation before the recall task. Results indicated that the recall rate of presenting a word in each of the two languages is approximately equal to presenting the same one twice in one language. There appears to be an interlingual equivalence of items.

Lopez and Young (1974) found positive transfer effects to be uniform both between and within languages. Subjects were given a set of words in English and Spanish to study before a free-recall task was administered. They reasoned that, if the two linguistic systems are dependent, then there should be positive transfer from one language to another. Results indicate a positive transfer effect and the common-store notion was supported .

In an investigation by Colletta (1975), subjects were presented with two items and had to judge whether they were the same or different with respect to synonym. Pairs of items were either homogeneous or heterogeneous in terms of language. It was hypothesized that there should not be any differences in

reaction time between the unilingual and bilingual conditions if there is only one memory store. No differences in reaction time between the two conditions were found offering further support for the single store hypothesis.

The Stroop-color-word task has also been used to show the interaction between languages (Dyer,1971; Preston & Lambert, 1969). In the usual form of the Stroop task, colour names are presented in a variety of ink colours. Subjects usually show considerable hesitation and interference when the colour names do not match the ink colours. Preston and Lambert reported that when bilingual subjects (e.g. French-English) were asked to name the ink colours in English, they showed interference if the letters spelled a French colour name that did not match the ink, though the interference was smaller than the conventional monolingual Stroop task. The Stroop colour word test indicates that bilinguals do not keep their two languages apart even when it is to their advantage to do so.

In a recent study by Potter, So, Eckardt & Feldman (1984) two experiments were conducted to investigate the lexical and conceptual representation in proficient and less proficient Chinese-English bilinguals. One group of subjects was required to read words aloud, name pictures and name translated words and another group of subjects was required to categorize pictures and words. Results from the two experiments offer support for the hypothesis that words in the two languages are directly associated to concepts that are not linguistic in form. In other words,

languages come together on a common conceptual ground, not by means of direct associations between lexical pairs.

In sum, the two extreme views, separate versus common-store, have become confused in the study of bilingual memory. Several investigators (Kintsch,1970; Hamers and Lambert,1972; McCormick,1977; Shanon,1982; Scarborough et al.,1984) proposed another perspective to conceptualize this issue. These researchers suggest that the answer to the question of bilingual memory may not be categorical but may depend on the demands of the particular task in cognitive processing. This conceptual framework differs from the perspective of representation, but is rather one of information processing. The concept of processing suggests that some processes may be carried out in conjunction with one type of representation, whereas other processes may be carrried out in conjunction with another. This perspective avoids the rigidity of the two dichotomies, separate-store versus common-store, and generates many more solutions to the issue of bilingual memory.

Kintsch (1970) offers evidence for this line of thought in a study of recognition memory. Bilingual subjects were given English or German nouns to remember. All items were repeated twice, either in the same language or with a language change. Subjects were to identify the occurrence of items according to some prescribed conditions. Kintsch (1970) observes that subjects can code words either in terms of language-specific cues or in terms of general semantic cues, as the task requires. However, certain

interference effects indicates that the two sets of cues are not totally independent.

In a study by Kolers and Gonzalez (1980), synonyms within languages, synonyms across languages , and exact repetition of words were compared as aids to recall. The authors attributed the bilingual equivalence of words to the skills developed by people in learning a second language i.e. direct association of vocabulary in the second language with the first language. Kolers and Gonzalez (1980) suggest that the bilinguals' linguistic representations are independent or dependent to the degree that particular skills are utilized differently in a given context or task. Bilingual equivalence of words is said to be due to the skills that people develop, of using and comparing them, not due to a common underlying semantic structure.

Altenberg and Cairns (1983) investigated the lexical processing in bilingual and monolingual subjects using phonotactic constraints. Stimuli were of four different types in terms of acceptability: "legal" in both languages, "legal" only in English, "legal" only in German, and "illegal" in both languages. The results of judgment tasks and lexical decision tasks indicates that the bilingual has a knowledge of two sets of phonotactic constraints. Moreover, both sets of constraints are simultaneously available to the bilingual and they interact during processing. This suggests that language specific constraints between two languages are related to task requirement.

In a recent study by Smith, Lockhart and King (1984), five

experiments were conducted to evaluate hypotheses concerning lexical organization in bilinguals. The first, second and third experiments each involved English-French bilinguals and demonstrated that interlingual transfer occurs in similar orthographies. However, transfer does not occur in tasks which emphasize meaning rather than translation. The fourth experiment involved English-Hindi bilinguals in a two-word lexical decision task with semantically related and unrelated words under pure and mixed language conditions. Results showed that semantic priming is present under both conditions. The final experiment demonstrated that for interlingual semantic priming to occur, related concepts must follow one another immediately. The overall pattern of results suggests that the units of lexical representation function in an integrated network, although the unit in bilinguals is language specific.

The experiments cited above represent specific attempts to analyze the interaction between the language specific store and language dependent store in bilinguals. Kolers and Gonzalez (1980) have suggested that the strategic control a bilingual can exercise over memory may have an effect on results obtained in different tasks. That is, a bilingual might appear to have a separate or an integrated memory system depending upon how task demands control encoding or retrieval strategies. Besides task demands, retention time also seems to have an effect on bilingual memory (Dornic,1979). Thus, taking these two factors into consideration may help in the analysis of the nature of the

tasks that support the two different views.

1.2.4. The Separate & Common Store Controversy and Working Memory

As mentioned before, some tasks encourage bilinguals to show language independence whereas others encourage bilinguals to show language interdependence in memory. Tasks showing a large degree of interlingual equivalence include interference in paired-associates learning (Kintsch & Kintsch,1969); positive interlingual transfer in multitrial free recall (Lopez and Young, 1974); interlingual facilitation in reading linguistically mixed material (Kolers,1966) and same-different judgment of synonym (Colletta,1975) etc. Tasks showing evidence for language-dependent effects include tests of recognition memory (Kintsch,1970; Scarborough et. al.,1984); word association tests (Kolers,1963); and single-trial free-recall (Tulving and Colotla,1970) etc.

Between these two types of task, there are differences which deserve attention. The various interlingual effects presented in the preceding section, as obvious support for a language-interdependent store, involve tasks that demand relatively long retention intervals and require more processing. Long term memory and more than physical cues (i.e. sound) are probably involved in these tasks. For example, same-different judgment of synonym requires subjects to retain words for a

relatively long time and to process words beyond the physical or phonological level. Retrieval of word meaning and comparison of word pairs are essential for the completion of the task. On the other hand, tasks that support a language-dependent store usually involve shorter retention time and demand less processing. When retention intervals are so short that subjects have no time to process information further, translation equivalents cannot be associated with old items. In other words, translation equivalents are not treated as old items when retention intervals are very short (e.g. Glanzer and Duarte,1971) and there is no tendency to confuse words of the same meaning. This tendency is consistent with the working memory model.

According to the working memory model, the articulatory loop is one of the subsidiary slave systems that helps the central executive (Baddeley,1984). Information is processed in the central executive where it is transformed into a speech-like code. It is then stored in a speech-like form in the buffer until recall. Thus, the role of retention time in the relationship between item information and language information of the tasks reflects general rules of memory functioning. Physical (i.e. phonological) cues prevail in immediate memory for tasks that require short processing time and short term retention.

Since items are processed into a speech-like code, no item information is stored without language information at this stage. The retention of the phonological code is a prerequisite for the retention of an item. Thus, in the working memory paradigm,

errors are of an all-or-none type; there are no real translation errors due to the nature of registration. In other words, bilingual processing is language-dependent in the working memory stage.

1.2.5. Working Memory and Comprehension

Baddeley and Hitch (1977,1985) suggest that a task as complex as reading may involve the working memory system and that it may be profitable to use the working memory framework to study reading. Baddeley (1979,1984) argued from the viewpoint of the working memory model that in learning to read, an individual must decode a series of visually presented letters, then store the outcome of his/her decoding in some temporary system, and subsequently blend the contents of this store to produce a word. He suggested that the articulatory loop system would be appropriate to assist in this. Each word is decoded and stored in the articulatory loop, thus freeing the central executive to decode the next word and hypothesize about the meaning of a sentence.

According to the working memory model, if processing is executed rapidly, then more capacity is left for storage and maintenance of the products of processing. Inefficient processes will be functionally equivalent to a smaller storage capacity.

Applying this model to reading implies that when the reading process is executed rapidly, more capacity is left for storing and maintaining the products of reading. If a reader requires less capacity to decode a word, his/her processing capacity will be more available for higher order integrated processes such as memory

for previously coded words or phases. In other words, if less time is spent on various stages of reading such as decoding, lexical access, parsing, inferencing and integrating, more capacity is available for storing the intermediate and final products of reading. Thus, the speed of processing information is crucial in reading comprehension.

1.2.6 Empirical Evidence Supporting Working Memory in Comprehension

Support of the working memory in reading comes from several studies. As early as 1931, Saunders reported clinical observations which associated poor performance on memory span with difficulties in reading. Moreover, the relationship between memory span and reading comprehension has been further substantiated by recent investigations.

Huelsman (1970) and Rugel (1974) reported that out of the 26 studies considered, 15 showed significant differences in performance between good and poor readers on the Digit Span Test. There were no instances in which the performances of reading disabled children were better than those of good readers. Moreover, a study by Owen, Adams, Forrest, Stolz & Fisher (1971) found that the Digit Span Test was one of the three subtasks which reliably differentiated between good and poor readers in elementary and junior high school.

Several studies (Heines & Leong, 1983; Wagner & Allan, 1983; and Manis,1985) using elementary students as subjects

suggest that memory span performance is correlated with reading comprehension.

Wagner & Allans' (1983) study offers further support for the working memory model. In their experiment, 30 grade four students were individually tested on a digit span test of working memory capacity and the Reading Span Test. The Reading Span Test was administered using sentences at a grade 2, grade 4 and grade 6 reading level. It was found that as the decoding demands of the stimulus sentences in the Reading Span Test increased, the working memory capacity available for other reading tasks such as comprehension decreased relative to a subject's working memory span as measured on the digit span test. Thus, the working memory capacity of an individual is a function of the interaction between the amount of central capacity required for processing operations and the amount of working memory capacity left over for storage.

Haines and Leong (1983) examined the advantages of visual and phonological processing of fourth, sixth and eighth grades by employing a vocalization task and a lexical decision task. Skilled readers performed better in both tasks in terms of speed and accuracy and from performance analysis, less skilled readers tended to make greater use of and had more difficulty with the phonological coding route.

The recent work of Manis (1985) also supports this conclusion. Word recognition skill in normal and disabled fifth and sixth-grade readers was examined. Subjects were required to

learn the meaning and pronunciation of unfamiliar words before performing a pronunciation task and a delayed pronunciation task. It was found that disabled readers were slower than normal readers in pronouncing unfamiliar words. Manis concluded that the deficient word-naming performances of disabled readers in all conditions indicates phonological and retrieval deficits as major sources of reading difficulties.

Using college students as subjects, similar results were obtained in several studies (Daneman & Carpenter, 1980; Mann, Liberman & Shankmeiler, 1980; Masson & Miller, 1983; Baddeley, Logie & Nimmo-Smith, 1985).

Daneman and Carpenter (1980) examined individual differences in working memory and reading. The results showed that subjects with large spans were better at abstracting a theme from a written or spoken narrative passage. In both listening and reading comprehension tasks, subjects with large spans scored much higher than subjects with small spans. In addition, the ability to abstract a theme from written narratives correlated significantly with silent reading span (r=0.71).

A set of experiments (Jackson & McClelland, 1975, 1979; McClelland & Jackson, 1978) examined the nature of the processing differences that separate better readers from less efficient readers by using undergraduate students as subjects. A large portion of the variance in reading ability can be accounted for by performance on tasks designed to measure the speed of memory access.

In a more recent study, Jackson(1980) investigated the relationship between skill and accessing letter codes from memory. Memory access was measured by the time taken to decide whether familiar and unfamiliar objects, letters and characters belonged to the same category or not. It was found that good readers performed better than poor readers only in the categorization of familiar objects and letters. This suggests that better readers were faster at accessing memory codes and that slow processing of memory codes may account for individual variation in reading performance.

In Masson and Miller's (1983) study, the ability to store and process information is shown to be positively related to scores on a standardized reading comprehension test, long-term memory encoding and retrieval of explicitly stated text information, and integration of text information for the purpose of drawing inferences. Therefore, it is concluded that in the task of reading, not only does the reader have to encode new information in working memory, but he/she must also activate recently processed information or related information held in long-term memory.

Other empirical evidence for the role of working memory in comprehension comes from studies of how individuals comprehend extended discourse. Baddeley, Logie, Nimmo-Smith & Brereton (1985) and Daneman & Blennerhassett (1984) have shown that individuals with smaller working memory spans perform more poorly on general tests of verbal comprehension and on specific tests of integration requiring them to compute a

pronoun's reference, monitor for semantic inconsistencies within and between sentences, and abstract the main ideas.

Likewise, Mann, Liberman and Shankweiler (1980) examined the differences in susceptability to phonetic interference by testing recall of phonetically controlled sentences and word strings and came to a similar conclusion. Results indicated that good readers made fewer errors than poor readers when sentences or word strings contained no rhyming words, but their superior performance disappeared when the materials contained many rhyming words. Mann et al.(1980) suggest that poor readers' defective performance is a problem involving a more general deficit in the use of phonetic coding in working memory as reflected in their inferior recall of phonetically nonconfusible sentences, word strings and letter strings.

Baddeley, Logie & Nimmo-Smith (1985) conducted two experiments to study individual differences among normal adults in performance on the Nelson-Denny reading test in order to cast light on the processes involved in reading. Experiment 1 correlated reading comprehension with performance on a variety of tasks. Working memory comprehension was found to be a significant factor as was lexical decision with nonwords, letter name matching, and vocabulary. A second experiment explored the working memory span task by comparing it with a nonlinguistic span test that was based on memory and counting. The verbal working memory measure again correlated significantly with comprehension. It is concluded that working

memory is one of the important components in reading comprehension.

Mann (1985) employed a cross-linguistic perspective to study the relation between short-term memory and early reading ability in Japanese second graders. Good beginning readers excel in memory for linguistic material such as Hiragana, Kanji and spoken nonsense words. This suggested that linguistic memory skills may contribute to successful acquisition of all orthographies.

In sum, research on both children and adults seem to support the working memory model which suggests that speed of processing information is important on the comprehension task. However, one needs to know whether it is the speed of lower-level (e.g. letter identification) cognitive processes or higher-level (e.g. integrating sentences) processes that contributes more to reading comprehension. It is mentioned in the review of the working memory model that memory span tasks are used to indicate working memory capacity. At least two processes are involved in memory span: item identification and item order (Das,1984). Thus, speed of item identification (i.e., word recognition) in reading may be a probable source to explain achievement in reading comprehension. On theoretical grounds, there is reason to support the proposition that word recognition is an important component of reading according to the working memory model. However, this model does not claim to be a model of reading. Reading is only one phenomenon which allows for testing and development of the

concept of working memory. Reading is a very complicated task that seems to involve a number of component skills. Many current models of reading in English discuss reading ability in terms of the cognitive processes in reading (e.g. Laberge & Samuels,1974; Perfetti & Lesgold,1977; Stanovich,1980). The general account of reading processes includes components of word recognition and comprehension. Thus, it is time to turn from the working memory model to reading models so as to examine the relationships between word recognition and reading skill.

1.2.7. Current Theories in Reading English

During the past decade, reading psychologists have attempted to conceptualize the reading process within the framework of information processing. A number of models of the reading process have been proposed and developed. Common to all of these models is the view that the reading process is a series of processing stages that occur between written symbols and meaning. However, these theoretical models differ in the extent to which they view the flow of information processing. The major distinction centers around the contribution of top-down or bottom-up processing. Top-down models conceive reading as mainly a concept-driven process. On the other hand, bottom-up models regard reading as primarily a stimulus-driven process. Yet another kind of reading model, the interactive model, so-called because of the interactive nature of both bottom-up and top-down processing, permits the explication of reading process in both directions. These

three types of models will be examined with emphasis on the role of word recognition and memory span in each of these models.

Top-down Models

For the top-down theorists, the flow of information processing is from the cognitive faculty downward to the stimulus. The top-down view presumes that the reader's conceptual and linguistic knowledge relevant to the content of the text imputes to comprehension, whereas a detailed analysis of input stimulus (i.e. analysis of letters, letter clusters, words and so on) is not regarded as necessary for comprehension. Readers act like hypothesis testers who confirm or reject hypotheses as they proceed through a printed page. The readers' prior knowledge of the world and language enables them to make informed predictions about what they are reading and thereby permits them to ascertain and reconstruct the author's written message. This conceptually driven process of reading has been strongly emphasized by Goodman (1970,1976) and Smith (1978,1979).

Goodman (1970) describes reading as a "psycholinguistic guessing game" requiring the reader to interrelate language and thought. His model assumes that the processing sequence starts with eye movement and a fixation on new material. Available language cues are then selected from perceptual input. The selection of visual information is guided by the reader's background, cognitive style, linguistic knowledge, strategies, and context contraints. A perceptual image is formed using these cues and the

reader's anticipated cues. The reader then searches his/her memory for related syntactic, semantic, and phonological cues to reform the perceptual image. At this point the reader makes a guess according to the graphic cues. This guess, resulting from semantic analysis, is stored in short term memory. If no guess is possible, the reader checks again or reviews the previous text. The guess is tested against the prior context for grammatical and syntactic acceptability. If the guess is acceptable, its meaning is assimilated with prior meaning and is consequently stored in long-term memory.

Goodman regards the reader's expectation as most important and deemphasizes precise analysis of graphic cues. Smith(1978,1982) holds a similar view to that of Goodman in that reading is essentially a process of hypothesis-testing. Smith (1982) describes reading as asking questions of printed text. Reading is purposeful, selective, anticipatory, and based on comprehension. The reader must make maximum use of "nonvisual information" and reduce the use of "visual information". "Nonvisual information", to Smith, is the reader's prior knowledge of the content of the text, and "visual information" is the surface structure of print. Smith (1979) asserts that the basic skill of reading lies more in the reader's conceptual knowledge than in identification of elements of print and "normal reading demands comprehension prior to and even without the identification of words" (p.119).

Both Goodman and Smith emphasize the top-down approach to reading. Lower level processes such as word recognition are

neither definitive nor essential to reading comprehension. Many researchers (e.g.Perfetti,1980,1983; Mitchell, 1982; Singer,1982) have pointed out several shortcomings of these top-down models. The main problems are the vagueness in conceptualization of the reading process and their deficiency in explaining competent reading. The contribution of conceptual knowledge to comprehension cannot be denied; however, it should not be regarded as the only factor affecting reading achievement. The use of high-level information does not eliminate the importance of other sources of information in reading.

Bottom-up Models

For bottom-up theorists, reading is viewed as analytic processing of print from word to meaning. This stimulus-driven process of reading is stressed by Gough (1972, and Gough & Cosky,1977). According to Gough (1972), reading is a sequential process of letter-by-letter, word-by-word, sentence-by-sentence analysis of print. As reading begins, visual information on the page is registered in iconic memory as a precategorical visual image. The identification of letters is assumed to operate serially from left to right by searching the long-term memory. The recognized letter string is placed in a Character Register and immediately operated on by a mechanism (the docoder). The letter string is then coded into a string of systematic phonemes by which the reader searches meanings for the words in his/her mental lexicon. The phonemic representation is used to identify the sequence of words in the

sentence, and these words are stored in primary memory to await the next process, sentence comprehension. Finally, when enough words have reached the comprehension device, a semantic referent is made.

The reading process in Gough's model is data-driven in that all decisions about visual stimulus, such as letters or words, must be made before the data are transformed into a meaning code to allow installation into long-term semantic memory. Higher-level information never serves to direct the hypotheses about what a particular word might be. Thus, reading is strictly bottom up, from lower-level sensory analysis to higher-level syntactic-semantic encoding.

Similar to top-down models, bottom-up models are not adequate in conceptualizing the reading process in that both these types of models appear to offer dichotomous explications of the reading process. These bottom-up models have failed to recognize the role of higher order knowledge and the impact of contextual processing on lower-level analyses (Rumelhart, 1977; Stanovich, 1980). No particular attention is paid to the process of integrating sentences and propositions, which plays an important role in reading comprehension. The ability to get the meaning of each word in a sentence, however, is not the same as what is meant by comprehending.

Interactive Models

In view of the deficiencies of strictly top-down and bottom-up

models, a third class of theory has emerged which emphasizes the interactive nature of the component skills in reading. This interactive aspect of reading is emphasized by Rumelhart (1977), Lesgold and Perfetti (1978), and Stanovich (1980).

Rumelhart (1977) has proposed a reading model which makes use of a formalism allowing parallel, interactive processing units. In the first stage of reading, graphemic information is registered in a visual information store (VIS). A feature extraction device is then assumed to operate on this information extracting the critical features from the VIS and then sending these features to the pattern synthesizer. The device draws upon a wide variety of different sources of information to work out the probable interpretation of the text. Rumelhart (1977) separates six levels of knowledge source -- feature, letter, letter cluster, lexical, syntactic, and semantic levels -- each of them is responsive to one dimension of a text. Information from all the different sources is brought together in the message centre. Each knowledge source then generates a set of hypotheses from the data available. Information is shared and evaluated simultaneously at all levels to sort out hypotheses that are consistent with one another and with the featural information. This set of hypotheses is then accepted as interpretation of the text.

In other words, reading is interactive because different level of processing are responsible for providing information and sharing the information with other levels. Comprehension is the process of synthesizing information provided from all levels. Knowledge sources, such as familiarity with the topic; the syntax and the lexicon,

affect reading performance.

Perfetti and Lesgold (1977,1979), Lesgold and Perfetti (1978) ; and Perfetti (1985) hold a similar view to that of Rumelhart in regarding reading as an interactive process, and develop a model of reading skill emphasizing verbal efficiency. Comprehension during reading involves higher-order processing of discourse structure and the reader's knowledge in interaction with lower-level word coding processes. However, the use of top-down and bottom-up data is not strictly reciprocal (Perfetti,1980). Although higher-level processes can begin with very little data provided by lower-level processes, the higher-level processes cannot occur prior to the beginning of lower-level processes (Perfetti & Roth, 1981). While higher-level processes can make lower-level processes more efficient, they do not affect the dependence of higher-level processes on lower-level ones. Reading processes are interactive but asymmetrical. Bottom-up processes can carry on reasonablly well without top-down processes, but not vice versa.

Perfetti and Lesgold (1979) have formed a bottleneck hypothesis stressing the limited capacity of working memory. This hypothesis assumes that reading comprehension processes share working memory resources with lower-level word processes. A processing bottleneck is created when the capacity of working memory is reached. To relieve this bottleneck, the resources devoted to word coding processes can be reduced by increasing the efficiency of word recognition. Hence efficient word recognition could be functionally equivalent to a larger storage capacity. According to

this hypothesis, single-word coding operations are a crucial part of reading and the faster the decoding takes place, the more working memory resources are available for comprehension processes.

Relating this bottleneck hypothesis to individual differences in reading comprehension, Lesgold and Perfetti (1977) suggest that the trade-off between processing and storage is a major source of individual difference. Slow coding processes deactivate memories of recently established contexts and therefore disrupt comprehension. Perfetti (1984;1985) provides some more specific components of verbal efficiency in his recent writings. He proposes two classes of hypotheses for explaining individual differences in processing efficiency. One hypothesis is that inefficient word access, which affects working memory is responsible for observed differences in memory and lexical processes. In other words, this hypothesis suggests that ineffective lexical access causes the appearance of a memory problem. This general proposal was made by Perfetti and Hogaboam (1975) and further discussed in detail in Perfetti and Lesgold (1977,1979), Perfetti (1977), and Lesgold and Perfetti (1978). The alternative hypothesis is that intrinsic working memory limitation is responsible for ability differences in reading. Low-ability readers may have effective lexical access but an ineffective working memory which fails to hold onto words or to the propositions it is encoding. Both of these hypotheses predict that low-ability readers will have less working-memory capacity than high-ability readers.

Perfetti (1984,1985) suggests that although word-level skills

are not sufficient for comprehension, word-level processes need to occur with minimal effort in order that working memory can be devoted to comprehension work. In assuming that reading is an interactive act, Perfetti points out that there are ways to compensate for inefficiency of lower-level processes. Thus, low-ability readers may be more dependent on context for word recognition than skilled readers. In this model, the manner in which attention is distributed and the primacy of verbal coding are essential parts of a model of skilled reading.

Similar to the model proposed by Lesgold & Perfetti (1977), LaBerge & Samuels (LaBerge and Samuels 1974; Samuels,1977,1982; Samuels and LaBerge,1983) proposed a limited-capacity model of reading. Their model suggests a relationship between attention and the subprocesses of reading. It describes reading as a process of activating internal codes corresponding to features, letters, spelling patterns, visual and phonological word coding, semantic word coding and ultimately to sentence comprehension. This model emphasizes the role of attention and automaticity in reading.

For LaBerge and Samuels, reading involves many lower-level subskills, i.e. letter and word recognition, and higher-level subskills, i.e. use of context cues in comprehension. In other words, reading can be viewed as a two-step process consisting of a lower-level task, decoding, and a higher-level task, comprehension (Samuels,1977). Since the amount of attention is limited, there is no problem if the reading task requires less attention than the reader has available.

However, if the attention required for a task exceeds attention capacity, the reader has to resort to a strategy to overcome this problem. Dividing the task into smaller units, where the attention required is within capacity limit, is one useful strategy. As reading is a complex activity, the attentional demands for the unskilled reader to perform the task may exceed the reader's capacity. Consequently, the task must be divided into subunits of decoding and comprehension. Not only must the poor reader further divide the task into decoding and comprehension, very often the words must be broken into smaller units. The size of the visual unit used for decoding depends on the attentional demands. In general, the less skilled the reader and the less familiar the words, the smaller the unit of visual processing would be. If decoding consumes too much attention, there will not be enough attention available for comprehension. Conversely, if the decoding process requires very little attention, the majority of the attentional resources can be used for comprehension.

Once the visual input is decoded, the visual units are processed into their corresponding sound representations in phonological memory. For highly familiar words, the phonological recoding stage may be bypassed and the processing route may go directly from visual memory to semantic memory, i.e. from print to meaning. The phonological information is then sent to semantic memory to process for meaning.

The importance of attention in reading is the focal point of the LaBerge and Samuels model. Samuels (1982) states that a student is

considered to be automatic at decoding when the decoding task requires so little attention that decoding and comprehension can take place simultaneously. Although automaticity in decoding will not guarantee good comprehension, it can be considered to be a prerequisite for skilled reading.

Lack of automatic decoding requires that the reader's attention be switched back and forth from word recognition to comprehension which consequently places considerable strain on the memory system. Automaticity in lower-level processing frees the reader's limited attention capacity to be centered on comprehension. The faster and more automatically the lower-level processes can be done, the better the comprehension process.

In addition to Rumelhart (1977), Lesgold and Perfetti (1978), & LaBerge and Samuels (1974), Stanovich(1980) also suggests an interactive compensatory model. Based on Rumelhart's proposal, Stanovich stresses the independence of processes at different levels and therefore suggests a possibility that a deficit in any processing level may result in a heavier reliance on any other processing levels. Stanovich (1980) argues that the interactive model allows a compensatory hypothesis which can better account for much of the research evidence of the reading literature. Combining the compensatory assumption with Rumelhart's interactive model, Stanovich (1980) states that the compensatory-interactive model of processing hypothesizes that a pattern is synthesized based on information provided simultaneously from all knowledge sources and that a process at any level can compensate for deficiencies at any

other level.

According to Stanovich's model, it is important to distinguish at least two types of contextual processing. Context can be used both to aid comprehension of text and facilitate word recognition during reading. The reader extracts meaning from text based on information provided simultaneously from several knowledge sources. When word identification is inefficient, the reader may draw from higher-level knowledge sources to aid word recognition. However, this kind of compensatory use of contextual information may facilitate word recognition, but it will also deplete the resources available for integrating the text, and consequently, the comprehension of the reader may suffer.

Summary of Reading Models

Different reading models view the flow of information processing from different perspectives. According to top-down models, the direction of processing is from the cognitive system downward to the stimulus. Higher-level processes are very important in directing lower-level processes. Bottom up models assume that the direction of processing is from data analysis up to higher-level contextual encodings. For interactive models, data-driven, bottom-up processing combines with top-down, conceptually driven processing to cooperatively determine meanings from text. The limited-capacity model suggests a relationship between attention and the subprocesses of reading and emphasizes the role of attention and automaticity in reading.

Despite differences among these models, the speed of processing is commonly recognized as being crucial for fluent reading to occur. Rapid word recognition is regarded as an important determinant of reading proficiency among these models. According to top-down models, individual word identification should be de-emphasized (i.e.,words should only be sampled from text) in order to have fast processing speed at the text level. On the other hand, bottom-up and interactive models emphasize the processing speed at the word level as an important factor in reading proficiency. For interactive models and the limited capacity model, the speed of word recognition is very important. For LaBerge and Samuels, rapid word recognition allows more attention to be centered on comprehension whereas in Lesgold & Perfetti's model, rapid word recognition frees working-memory capacity for comprehension. Most of the theoretical arguments just reviewed favour a relationship between rapid word recognition and reading comprehension. It is time to turn from theory to research to examine the empirical relationships between word recognition and reading ability.

1.2.8 Empirical Research in Reading English

Many studies have attempted to examine the empirical relationships between word recognition skill and reading ability. Presented below are some research findings of eye movements on lexical access in reading, and studies investigating the relationships between word recognition and reading ability with respect to word

recognition speed.

Eye Movement Research

Studies of eye movement (Just and Carpenter, 1980;1981, Rayner 1975, 1978) show the importance of word recognition in the reading process. Just and Carpenter (1980) examined the gaze durations of college students while reading. The data showed that most words in the text are directly fixated during ordinary reading. Another study by Carpenter and Just (1981) found that over 80% of the content words and many function words are fixated. In addition, word length and frequency affects the duration of fixation. Long words and low frequency words are fixated relatively longer than short words and high frequency words. Besides fixations, narrowness of the perceptual span also has an effect on reading. Rayner (1983) reported that readers generally cannot determine the meaning of a word that is in the visual periphery. Perceptual span for specific word recognition is only a few letters. The studies described above demonstrate that reading cannot occur without reading words and word recognition is crucial in reading.

Studies of word recognition speed

In a wide variety of studies investigating children as well as adult readers, the ability to recognize words is found to be highly correlated with reading proficiency. In a longitudinal study, Stevenson, Park, Wilkinson, Hegion, and Fish (1976) reported high correlations between word reading tests and comprehension tests for

the first three grades in elementary school. The correlations were approximately 0.78 for second graders and 0.8 for third graders.

ln an extensive study, Biemiller (1977-78) demonstrated that letter and word perception is an important part of reading. Using subjects from grade two through adult level and materials ranging from a primer to college texts, Biemiller found large time lags for poor readers in reading words, especially when they were required to read word in isolation.

McCormick and Samuels (1979) reported that word recognition accuracy and latency were significantly correlated with comprehension ability for grade two children. The correlations between word recognition accuracy and comprehension ranged from 0.49 to 0.7 whereas the correlations between word recognition latency and comprehension ranged from -0.54 to -0.56.

Deno, Mirkin, and Chiang (1982) conducted three concurrent validity studies to determine the relationship between performance on formative measures of reading and standardized reading tests using grade one through grade six regular and resource program students. Three reading-aloud measures -- words in isolation, words in context, and oral reading -- all related closely to achievement on standardized reading tests. The correlations ranged from 0.73 to 0.91.

Studies using correlational analyses suggest that high speed of word recognition is associated with high comprehension. The correlations were in the range of 0.5 to 0.8. ln a different kind of research paradigm, where lexical decision tasks were used, results

also support the claim that fast word recognition is a skill which differentiates good from poor readers.

Perfetti and Hogaboam (1975) measured vocalization latencies for high frequency word, low frequency words and pseudowords of good and poor readers from grade two to six. They found that in all three cases skilled readers had shorter vocalization latencies than less skilled readers. While skilled and less skilled readers showed smaller vocalization latency differences (approximately 200 msec) for high frequency words, skilled readers were far superior (one second faster) in vocalizing low frequency words and pseudowords. These results suggest that decoding skills are important in reading comprehension, at least in the middle grades tested.

Hogaboam and Perfetti (1978) examined the effects of subword units and word experiences on third and fourth graders' word decoding speeds. They found that the vocalization latencies of poor readers were more affected by the number of syllables in a word than those of good readers. The average difference between one and two-syllable words ranged from 240 to 330 msec for skilled readers, and it was about 780 msec to one second for poor readers. Results indicate that subword decoding processes are a source of decoding differences between good and poor readers. In order to examine the effect of word experiences on decoding differences, a second experiment was conducted in which skilled and less skilled fourth-grade readers were provided with equal amounts of aural, visual, and semantic experiences with pseudowords. It was found

that aural and visual experiences with pseudowords shortened vocalization latencies for all readers, but meaning experience added nothing. Moreover, equal experiences did not lead to equal reaction times. Skilled readers were faster in decoding the words even when previous word experiences were equated. Results suggested that word experiences are not wholly responsible for the decoding differences between good and poor readers. In the third experiment, Hogaboam and Perfetti investigated the effect of different quantities of word experiences. Good and poor readers received aural and visual experiences with pseudowords varying from zero to eighteen times spread over three days. It was found that good readers benefited relatively more from aural exposures than poor readers. Good readers are faster in showing gains in decoding speed.

In another experiment, Perfetti, Finger, and Hogaboam (1978) examined good and poor readers' ability to name words colours, digits and pictures. It was found that good and poor readers named colours, digits, and pictures at a similar rate. However, in tasks involving words, there were significant differences between good and poor readers. Perfetti et al. (1978) suggest that poor readers are deficient in coding alphabetic stimuli.

The Perfetti, Finger, and Hogaboam (1978) study was replicated by Stanovich (1981) using first-grade readers. A letter naming condition was added in addition to the tasks employed by Perfetti et al. (1978). The study replicated the basic findings of Perfetti et al. (1978) that there are no significant differences in digit, colour, picture, or letter naming between the two groups. Only in

tasks involving words are there significant differences between good and poor readers.

Ehri and Wilce (1983) investigated the development of word recognition speed in children of different grades. The researchers asked skilled and less skilled readers in first , second, and fourth grades to name digits, pictures, familiar words, and consonant-vowel-consonant nonwords. Maximum speed with familiar words was displayed by skilled readers in all grades but by less skilled readers only in fourth grade. Maximum speed with consonant-vowel-consonant nonwords was found in skilled readers of second and fourth grades, but not in less skilled readers at any grade. These findings support the fact that word recognition skill differentiates good from poor readers. Moreover, Ehri and Wilce (1983) found some results which are not completely consistent with the results of Perfetti et al. (1978) and Stanovich (1981). Ehri and Wilce (1983) observed that skilled readers named pictures and digits significantly faster than less skilled readers.

In another study by de Soto and de Soto (1983), a picture naming difference between good and poor readers has also been found. Verbal processing abilities in fourth-grade good and poor readers were tested through various tasks -- memory span, associate learning, semantic association, automatic word processing, and naming speeds of pictures, words, and pseudowords. These researchers found that good readers performed better than poor readers on all tasks except automatic word processing. It is suggested that the words in the automatic word processing task

were so familiar that both groups of readers could process them automatically. Another finding is that rapid verbal coding of visual stimuli can differentiate good from poor readers.

The lack of agreement among these four studies may be due to subject differences and/or differences of experimental procedure. Despite the different findings on processing nonalphabetic stimuli, all four studies demonstrate that rapid word recognition is the most reliable skill distinguishing good and poor readers.

As evidenced by the above studies, skilled elementary school readers are markedly superior to poor readers in their ability to name words accurately and rapidly. It is time to turn to studies which investigated this issue using adolescents as well as adults as subjects.

Briggs and Underwoods (1982) examined phonological coding in good and poor readers using a picture-word interference task and a vocalization task. Results indicate that poor readers, both children and adults, were significantly slower to name words and nonwords than good readers.

Using college students as subjects, Mason (1978) examined good and poor readers' speed in decoding high frequency, regular, and irregular words. It was found that poor readers were slower and made more errors than good readers in decoding regular and irregular words. The performance of poor readers was worst in decoding nonwords which required phonological coding. Results suggests that even in adults, rapid and acccurate word recognition is very important in reading.

Jackson and McClelland (1979) required college subjects to perform a number of reaction-time tasks and a listening comprehension task. It was found that listening comprehension and letter matching are the two best predictors of reading effectiveness. It seems that access to letter codes is an important factor in adult reading ability.

In a study by Hammond (1984), college subjects were required to perform word and pseudoword naming tasks in addition to the letter matching task like that in the Jackson and McClelland (1979) study. It was found that vocalization speed significantly differentiated good from poor readers. Moreover, after controlling for the correlation between letter matching and reading ability, the correlation between naming latency and reading ability still remained significant. Thus, decoding is important in the reading ability of adults.

Longitudinal studies by Lesgold and Resnick (1982) and Lesgold, Resnick, and Hammon (1985) examined the relationship between word recognition skills of several groups of children in different instructional programs from grade one to three. The sample of children were categorized as being of high, medium, or low reading skill. Each subject was given tasks including word vocalization, semantic judgment, and oral reading speed at each test point. Using path analysis, Lesgold and Resnick found that there were strong causal paths between each speed variable, but no path from comprehension to a subsequent speed measure. These results provide evidence that rapid word processing is a crucial component

of reading and, more importantly, it is a cause of good reading skill. Thus, word recognition skill is a cause rather than a consequence of fluent reading.

Studies concerning word recognition automaticity and word recognition speed have all pointed to the repeated finding that accurate, automatic, and rapid word recognition is a crucial factor distinguishing good from poor readers. The longitudinal studies by Lesgold and Resnick(1982) and Lesgold, Resnick, and Hammond, (1985) suggests a causal link between word recognition speed and comprehension ability. From the available literature, it can be concluded that the relationship between word recognition skill and reading ability is well documented. Moreover, within the working memory paradigm, there are evidences supporting the proposition that word recognition is an important component of reading. However, whether rapid recognition of words also bears an important relationship to comprehension in a logographic language, Chinese, is still an issue.

1.2.9. Theoretical Issues in Reading Chinese

Characteristics of the Chinese Language

The Chinese writing system has several characteristics that are distinct from other languages. Chinese as a logographic language is best characterized as monosyllabic, isolating, and analytic (Leong, 1973, 1978). The smallest meaningful unit in Chinese is the character and it is monosyllabic. Thus, each Chinese character is a

one-syllable morpheme. Moreover, the Chinese character remains constant in shape regardless of syntactic changes. Chinese is analytic in nature because there are few bound forms in the language.

Six Categories of Characters

Chinese characters are structurally composed in a symmetrical and balanced way. There are rules to classify characters into groups according to the way the character is formed. There are six categories in which Chinese characters can be grouped: (1) pictographs; (2) simple ideograms; (3) complex ideograms; (4) phonetic loans; (5) derivatives; (6) phonograms. Pictographs are designed to have an iconic relation with the objects they represent. Simple ideograms convey ideas which can be understood by looking at the character e.g. "上" means up, "下" means down. Complex ideograms contain two to four pictographs or ideographs to suggest an idea e.g. 'tree' repeated twice is 'forest'. Phonetic loans are those characters borrowed for new characters based on the identity of sound. The characters for 'wheat' and for 'to come', were homophones in Archaic Chinese. Because an iconic representation is much more complicated for 'to come' than for 'wheat', the character for 'wheat' was loaned for the latter. Derivatives are new characters derived from old ones. They usually have similar meanings but different sounds. Phonograms are also made up of two or more components and one of the components is used for its phonetic value. For a phonogram with two components, the reader gets a hint as to its meaning from the radical and as to its pronunciation from the

phonetic. According to Taylor and Taylor (1983), about 80-90% of the characters are estimated to fall into this category. Given this a high proportion of phonograms, the statement that Chinese script is nonphonetic is obviously not true for some of the logographs.

Phonetic and Radical

There are some 800 phonetics, which cue the sounds of characters (Taylor and Taylor, 1983). A phonetic allows experienced character users to guess, but not to ascertain, the sound of a character. The success rate of using a phonetic to predict a character's sound is approximately 0.39 (Zhou, 1978).

There are 214 radicals, which cue meanings of characters (Taylor and Taylor, 1983). Radicals serve as classifiers of characters in Chinese dictionaries. The radicals can be grouped into four semantic categories: (1) nature; (2) flora; (3) fauna and (4) man (Taylor and Taylor, 1983).

Although a character is the smallest morphemic unit in Chinese, most modern Chinese words are composed of more than one character. A word like "student" has two characters in Chinese which literally mean "learning person". The basic sentence in Chinese has a clear word order of subject-verb-object. Chinese morphemes do not inflect but remain unchanged regardless of syntactic changes. Thus, one character may serve as 'go, goes, went, gone' and 'going'. The orders in which characters are used in a sentence define their grammatical classes.

Because of these characteristics Chinese is best described as

monosyllablic, isolating, and analytic. There are six categories to classify Chinese characters : pictographs, simple ideograms, complex ideograms, phonetic loans, derivatives and phonograms. Most Chinese words consist of two or more characters. Chinese characters are noninflecting morphemes whose grammatical classes depend on word order.

Learning Characters

The concept underlying the development of Chinese characters is the mapping of written symbols directly into meaning. Characters are learned by the holistic method. A character as a whole visual pattern is associated with its sound (syllable) and meaning (morpheme). Children learn 2500 - 3000 characters over a period of 6 years in primary school. They learn the " easy " ones first and then progress to more " difficult" ones. Easy characters usually contain fewer than 10 strokes, are easy to discriminate, and are composed of vertical and horizontal strokes (Ai,1950). The minimum number of characters required for a person to function adequately in daily usage is about 3500 (Leong, 1973). The reason Chinese can manage with a relatively small number of characters is because of the freedom with which they can be combined into words. Remember that the use of 3500 characters does not mean that there are only 3500 words: characters combine to form multi-character words, such as 'student ' which is composed of two characters, 'learning' and 'person'. It is estimated that there are 16,000 commonly used characters (Liu, Chuang, and Wang,1975).

The large number of characters introduced in the learning process leads many researchers to speculate on the importance of visual discrimination and rote memory in learning to read Chinese . However, there are rules and strategies in encoding Chinese characters which reduce the burden of rote memory. Ai (1950) reports that using the six categories of classification facilitates children's learning of characters. He found that the children learned much faster when the six categories were explained than when they were ignored. Similarly, Liu (1978) also observed a dramatic increase in acquisition of vocabulary by Grade 4 children when the principles were taught to them.

A child learning Chinese faces a similar linguistic structure as a child learning English. Wang (1973) argued that the information content of the strokes in a character is comparable to that of letters in English. Being the smallest meaningful units, Chinese characters are the basic component of multisyllablic words. Thus, Chinese characters are comparable to syllables in English.

In view of the logographic writing systems in Chinese, the task demands imposed by this orthographic structure may be different from the alphabetic writing system. Reviewing the empirical research done in the Chinese language may provide some information about this issue.

1.2.10. Empirical Research in Reading Chinese

Chinese characters and alphabetic letters differ in appearance, sound coding and meaning extraction. These

differences may affect the ways in which characters and alphabetic letters are perceived, remembered and read. Researchers have attempted from an information processing approach to reveal the fundamental properties of reading Chinese. Numerous experiments have been carried out to answer the question of which hemisphere processes Chinese characters. Moreover, coding processes in reading Chinese have also received attention recently.

The human cerebral cortex is divided into a left hemisphere and a right hemisphere and each has different functions. The left hemisphere has analytic and sequential capabilities, whereas the right hemisphere has imagic and holistic functioning (Taylor and Taylor, 1983). Language is usually processed by the left hemisphere as it requires sequential and analytic processing. Visual spatial material is usually processed by the right hemisphere.

In experiments employing the visual hemifield experimental paradigm, in which verbal materials are tachistoscopically presented to either the right or the left of a central fixation point, a right visual field superiority effect in processing alphabetic material has been established (Milner,1975; Moscoritch, 1979; Sperry, Gazzaniga, and Boger, 1969). It is postulated that English words enjoy a right visual field advantage because the phonetic coding required for processing alphabetic materials is carried out in the left hemisphere. Since most experiments demonstrating the right visual field superiority effect have used alphabetic stimuli, the results may not be generalized to other nonalphabetic materials such as Chinese.

Two main approaches have been used to examine the

hemispheric processing of Chinese characters, namely the study of brain lesions, and the study of visual lateralization effects with respect to Chinese characters and Japanese kana scripts. The first is to study the effects of brain lesions on reading behavior and thereby infer the psychological functions of the nervous system. Sasanuma (1972, 1974a, 1974b, 1974c) has used this approach in several studies of Japanese aphasics.

Japanese consists of three different types of script. Most words in Japanese are written in Chinese characters (kanji) while grammatical particles and loan words are usually written in kana script. Each symbol in kana represents a syllable of the spoken language. Thus, when Japanese speakers suffer brain damage, there is a possibility that they may be selectively impaired in either kanji or kana. Sasanuma and Fujimura (1971) tested aphasics in visual recognition tasks. The subjects consisted of two types of aphasics with right-sided paralysis, and two types of nonaphasics with either right- or left-sided paralysis. Both kanji and kana were presented as stimuli. It was found that the nonaphasic groups made no errors in recognizing either type of word. The simple aphasics made some errors and to similar degrees on both types of words. However, the aphasics with apraxia of speech made far more errors on kana than on kanji. These results suggest that the right hemisphere is responsible for phonetic ability since kana must be phonologically processed before the word is identified. Impairment in the right hemisphere seems to affect kana processing more than it does kanji processing.

Sasanuma (1974a, 1974b, 1974c) reported a series of studies that consistently showed some evidence for the selective impairment of kana and kanji. She has argued for differential disruptions of language, attributable to a particular lesion in the left hemisphere, after examining the characteristics of the aphasics' speech production and reception. The fundamental difference between kana and kanji is the suggestion of phonological processing for kana in which graph-sound-meaning correspondence is essential in identifying the words. Selective impairment of kana processing occurs in subjects with damage to Wernicke's area, Broca's area, or the Arcuate fasciculus. A number of subjects show impairment of kanji processing with lesions in the area surrounding the Wernicke-Broca area complex.

The clinical studies by Sasanuma provide some evidence for the hemispheric processing of Chinese characters. However Tzeng, Hung, and Garro(1978) suggested two apparent shortcomings that cannot be avoided in this type of research. The first is that the number of cases involved in most clinical studies is usually small, which makes statistical evaluation impossible. Second, the results from clinical studies are difficult to generalize to the normal population.

In view of the shortcomings of clinical studies, corresponding experimental evidence has to be established with normal subjects. The second approach that has been used to examine the cerebral lateralization functions for processing Chinese characters is to study visual lateralization effects with respect to kanji and kana scripts.

Hirata and Osaka (1967) and Hatta (1976) found a superior performance of the left hemisphere in recognizing kana characters. Subjects produced more errors in a recognition matching task when stimuli were presented first to the left visual field and then to the right visual field. This indicates left hemisphere superiority for kana which is consistent with the results obtained with alphabetic writing.

In another experiment, Hatta (1977) measured recognition accuracy of kanji characters in both visual fields. Left visual field (right hemisphere) advantage was found for both high and low familiarity kanji in normal Japanese subjects. This indicates that kanji characters are processed in the right hemisphere.

Three experiments on visual lateralization effects using Chinese characters were conducted by Tzeng, Hung, and Cotton (1978). In the first experiment, a left visual field (right hemisphere) advantage was found for processing single characters regardless of whether or not the character contained any phonetic clue. In the second experiment, the opposite result -- evidence of right visual field (left hemisphere) advantage -- was obtained when stimuli were multi-character words. This result suggests a left hemisphere dominance for processing multi-character words to clarify the issue. Subjects were requested to make a semantic decision on multiple-character terms by pressing a key to indicate answers. The results of this experiment again show a right visual field (left hemisphere) advantage.

Tzeng et al. attributed the seemingly conflicting results to the function-specific property of the two hemispheres, and they rejected

the orthography-specific localization hypothesis. Holistic recognition of single characters is better handled by the right hemisphere whereas sequential and analytic processing for semantic judgment is better handled by the left hemisphere. This interpretation was further supported by Elman's results (1980, as cited in Tzeng and Hung,1981) showing that with single characters, only the simple naming task shows a right hemisphere dominance; a more complicated classification task indicates a left hemisphere dominance. In a more recent study, Zhang & Yang (1986) also found a right visual field (left hemisphere) superiority effect for both Chinese and Japanese subjects in recognizing single words, compound words and abstract words.

Hirata and Osaka (1967) and Hatta (1976) found a superior performance of the left hemisphere in recognizing kana characters. Subjects produced more errors in a recognition matching task when stimuli were presented first to the left visual field and then to the right visual field. This indicates left hemisphere superiority for kana which is consistent with the results obtained with alphabetic writing.

Consistent with the results obtained from the study of Tzeng, Hung, Cotton, and Wang (1979), Hatta (1981) reported similar results using Japanese college students as subjects. Three experiments were carried out in which the subjects were instructed to perform tasks of pattern matching, lexical decisions, and semantic comparison of kanjis. The results showed a right hemisphere advantage in pattern matching, no hemispheric difference in lexical decisions, and left hemisphere advantage in semantic comparison of

kanjis. From the results obtained, Hatta suggests that there are different stages of processing kanji. The right hemisphere seems to contribute more in perceptual matching whereas the left hemisphere seems to contribute more in semantic comparisons. However, in lexical judgement, both hemispheres contribute equally during the process.

In summary, it seems clear that visual lateralization effects for Chinese characters vary with task demands. Initial perceptual processing of Chinese characters is like a pattern-recognition task and the contribution of the right hemisphere is greater. However, for further linguistic analysis of Chinese characters which involves phonological or semantic components, the contribution of the left hemisphere is considerably stronger. In short, when linguistic processing is necessary, lateralization effects for processing verbal materials often point to left hemisphere dominance, regardless of language.

Another issue concerning Chinese characters is the claim that phonetic recoding can be avoided in reading Chinese. As Chinese characters are logographic symbols, greater perceptual demand may be involved in reading Chinese.

Biederman and Tsao (1979) reported a comparative study in which Chinese subjects were asked to perform a Chinese version of the Stroop colour-naming task, and American subjects an English version. The researchers attributed the difference in performing the Stroop task to the possibility that there may be greater perceptual demands involved in reading Chinese than in reading English. Single

characters tend to be processed by the right hemisphere, which is involved also for processing colour. Thus, the reading of Chinese characters and identifying colour information may be in competition for the same perceptual capacities, whereas reading English and colour naming are executed by different mechanisms.

Fang, Tzeng, and Alva (1981) examined intra-language and inter-language effects using bilingual subjects. It was found that for Chinese-English bilingual subjects inter-language colour naming produced less interference effect than did intra-language colour naming. The investigators attributed the difference to the possibility that Chinese and English represent two different orthographies. Switching from one to the other may enable the bilingual subjects to employ different processing strategies and consequently cause them to be released from the Stroop interference.

In processing Chinese characters, the configuration of a character plays an important role, and greater perceptual demands are required. It is commonly assumed that the access code during reading is mainly visual and direct. However, the results of phonological coding studies provide a different picture.

Tzeng and Hung (1980) reported three experiments related to phonetic recoding in reading Chinese materials. In the first and second experiments, Chinese subjects were required to make graphemic, phonetic, semantic or sentence judgments about strings of characters with or without a concurrent shadowing task. The shadowing task required subjects to repeat digits in Chinese delivered through a headphone, a task which was presumed to interfere with

phonetic recoding. It was found that only phonetic decisions and semantic judgments were seriously affected by the shadowing task. It is suggested that phonetic decisions and semantic judgments require phonetic recoding. In the third experiment, Chinese subjects were instructed to read a section of prose and circle all characters containing certain grapheme components at the same time. It was found that subjects detected characters most often when the designated grapheme component was embedded as a phonetic in the characters.

The results of all these experiments demonstrate that phonetic recoding does play an important role in reading Chinese characters. Treiman, Baron and Luk (1981) hypothesized that phonetic recoding was a necessary processing strategy of English readers, but it was used to a lesser extent by readers of Chinese. They examined the performance of Chinese readers and English readers on two types of sentences: homophone sentences and control sentences. Homophone sentences contained a homophone word so that the sentence would sound correct if read aloud. Results indicate that Chinese readers are significantly less impaired by homophone sentences than are English readers. It is suggested that speech recoding is used less by readers of Chinese.

While not denying phonetic recoding in reading Chinese, evidence also indicates the use of visual coding in processing Chinese characters in working memory. Yik (1981) manipulated some single character pairs in acoustic similarity, others in visual similarity. In addition to a strong acoustic similarity effect, a strong visual

similarity effect on memory was also obtained. The visual effect was particularly strong in the absence of acoustic similarity between the characters. It is suggested that while acoustic encoding is a basic characteristic of short-term recall processes in reading Chinese, visual encoding in short-term memory is also needed as the situation demands.

In Chu-Chang and Loritz's (1977) study, Chinese high school students were asked to identify previously shown Chinese characters among phonetic distractors, visual distractors, and semantic distractors. The largest number of errors in recognition was found in the condition with phonetic distractors, next with visual distractors. The researchers suggest that the short-term memory representation of written Chinese characters is predominantly phonological.

Spoken duration of words has been shown to have an effect on memory. Baddeley et al. (1975) reported that memory span for words is a simple function of their spoken duration. Words that can be named more rapidly are better recalled than words that require longer articulation time. Thus, Chinese and English may affect memory span differently in terms of their acoustic characteristics.

Hoosain (1984) found that a Chinese superiority effect for digit memory occurs among Cantonese speakers residing in Hong Kong. When subjects were asked to pronounce a list of 200 random numbers as quickly as possible, Hoosain found a mean pronunciation duration per digit of 265 ms, a value considerably faster than the 321 ms found for English by Ellis and Hennelly (1980). For Chinese-English bilinguals, digit span in Chinese is longer by 2 digits

than in English.

Likewise, in a study by Stigler and Lee (1986) comparing short-term memory for digits between native speakers of Chinese and of English, similar results were obtained. The Chinese subjects, at kindergarten to second-grade level, remembered at least 2 more digits on average than did American or Japanese subjects. Stigler & Lee (1986) attributed this difference to the differences in pronunciation duration of Chinese and English number words. Chinese number words are found to be of shorter pronunciation duration than English number words.

In sum, both visual coding and phonological coding are used in processing Chinese materials. Phonological coding is usually needed at the working-memory stage of text comprehension and visual coding is necessary for discriminating homophones. Moreover, memory span in Chinese is relatively longer than in English due to shorter pronunciation duration.

Summary of Empirical Research in Reading Chinese

A review of the psychological research on the Chinese language within the information processing paradigm indicates that there is a left hemisphere dominance in processing Chinese as well as English. Both visual involvement and speech recoding also occur in reading Chinese. Moreover, there is evidence suggesting that there are similar word recognition processes in both languages. However, the Chinese language has an effect on memory span due to shorter spoken duration. A superiority effect for memory span task in

Chinese is found.

Summing up the findings of the studies reviewed , it appears that in processing Chinese and English, there may be processing differences at the lower levels, but similar linguistic techniques are involved in the later stages. Chinese and English words are processed differently in terms of cerebral lateralization functions, perceptual demand and coding pathways. However, high-level processing seems to be universal across languages. From available data, phonetic recoding was found to occur in reading both Chinese and English. Thus, a phonetically based working memory for reading is required for both writing systems. Word recognition processes are very similar in reading different orthographies. It is therefore logical to hypothesize that word recognition may have a similar important relationship to reading comprehension in Chinese as it does to reading comprehension in English.

On the other hand, the two languages have different effects on memory capacity. Longer memory span is found for Chinese due to the shorter articulation time required for that language. Thus, it is reasonable to hypothesize that while memory span has a similar relationship to reading in both languages, longer memory span may affect reading in Chinese in different ways.

Similarities and differences in processing Chinese and English have been discussed. However, acquiring both languages by one individual is different from learning one of them exclusively. Being bilingual may have an effect on reading

comprehension in the native and the second languages.

1.2.11. Empirical Research in Bilingual Reading

The tendency towards multilingualism is a natural consequence of the technological and cultural development of the world today. ln some countries, people are using languages other than their mother tongue.

Bilinguals often have been the object of research into cognitive processes. One reason for research interest in bilinguals is that some aspects of a specific skill may be relatively weaker in one of the languages even though these bilinguals may demonstrate equivalent speaking, listening and reading skills in their two languages. Many bilinguals who are normally fluent in their second language may read more slowly in that language than in their first language. Non-balanced bilinguals are most typical in the world today. lt is these types of bilinguals who frequently face serious problems when having to process information in their weaker language. Daitchman (1976) has found evidence suggesting that the difficulties encountered by bilinguals reading in the second language need not be due to an inadequate knowledge of the language; i.e. syntax and vocabulary may not be the main reason for the poorer performance in the bilinguals' second language. In Daitchman's (1976) study, bilinguals with fluent listening and speaking abilities were required to read and listen to passages of comparable difficulties in either their first or second language. lt was found that although

subjects comprehended spoken materials equally well in both languages, their comprehension of written materials was inferior in their second language when compared to that in their first. The second language reading difficulty may arise, in part, from a reduced sensitivity to orthographic, syntactic, and semantic redundancies and ambiguities in the second language. This suggests that bilinguals may take a longer time to process information in their second language.

Slower second language reading has been associated with differences in the fixation time of eye movements. Oller and Tullius (1973), found that non-native readers of English fixated for a longer duration than did native readers despite equivalent comprehension and similar numbers of fixations and regression per line. Since the duration of fixation presumably reflects information-processing time (Rayner, 1978), it appears that bilinguals require more time in the second language than in the first to process the same amount of printed information.

lt has been shown in Chapter four that despite the differences among reading models, the speed of processing is commonly recognized as being crucial to reading.

The Stroop task has been used to study language processing of bilingual individuals. The standard finding as reviewed in Chapters two and five is that colour-naming interference is greater in the within-language condition than in the between-language condition. The pattern of between- and within-language interference is determined by language similarity:

When the similarity of colour names in the two languages is low, greater within- than between- language interference is found, whereas equivalent between-and within-language interference is found when the colour names in the two languages are similar. However, Magiste (1984) suggests that the patterns of within- and between-language interference may also be determined by the degree of language proficiency.

Magiste (1984) investigated the roles of language proficiency and language similarity in between- and within-language interference in German-Swedish bilinguals with the Stroop color-naming task and a picture-naming task. Colour names in German created greater colour-naming interference than those in Swedish for subjects with the least knowledge of Swedish, regardless of which response language was used. The greater interference produced by German relative to Swedish words disappeared for subjects with about three or more years of residence in Sweden. For subjects with 10 or more years in Sweden, colour names in Swedish produced greater color-naming interference when the response was in Swedish, whereas both types of interference were about equal when the response language was German. These results seem to suggest that the pattern of Stroop-interference is determined by the degree of language proficiency.

In a study by Chen and Ho (1986), two languages with dissimilar structures, Chinese and English, were used to investigate the development of Stroop interference in

Chinese-English bilinguals. Bilingual subjects in Grades 2,4,8, and 10 and in college used both Chinese and English to name the colours of patches and Chinese and English words that consisted of incongruent colour names. The results showed that for all subjects, colour names in Chinese created greater colour-naming interference than those in English when subjects responded in Chinese. However, when the response was in English, presenting colour names in English rather than in Chinese produced greater colour-naming interference after Grade 4. For subjects with the least knowledge of English, giving colour names in Chinese created greater colour-naming interference than presenting them in English regardless of which response language was used. These results suggest that the pattern of the between- and within-language interference in bilinguals is determined both by language similarity and language proficiency. Thus, bilinguals may process their first and second languages at different speeds due to differences in language similarity and language proficiency.

Favreau and Segalowitz (1980,1983) demonstrated that bilinguals with slower second language reading skills require a longer time in processing words in that language. In their 1980 study, they used English-French bilinguals with balanced listening skills, but slower second language reading skills, to participate in two-letter recognition tasks. lt was found that subjects needed additional processing time to demonstrate a word superiority effect in the second language. This study shows that

skilled bilinguals are less efficient in processing information in their second language than in their first language.

In a more recent study, Favreau and Segalowitz (1983) examined whether, compared with first language reading, slower second-language reading is associated with reduced involvement of automatic processing during lexical access. Subjects were French-English bilinguals with equivalent comprehension of their first and second languages under ordinary conditions of communication. Half of these subjects read their first and second languages equally rapidly, and half read the second language more slowly than the first. Subjects were tested on a lexical decision task in both languages. It was found that bilinguals with equal first and second language reading rates produced results suggesting automatic processing in both languages. However, bilinguals with unequal reading rates produced results indicating reduced automatic processing in their second language.

In a study by Standing, Smith and Isely (1980), bilingual subjects were given CVC (consonant-vowel-consonant) nonsense syllables to read and memorize. Subvocalization time and memory span were found to be highly correlated. Moreover, memory span decreased dramatically and subvocalization time increased proportionately by testing in a bilingual subject's second language. This seems to suggest that second-language operations require more processing capacity or resources than do first-language operations for unequal reading-rate subjects.

The studies reviewed are consistent with a suggestion by

Dornic (1980) that for many bilinguals there is less spare processing capacity available when they are working in the second language. Dornic (1980) required bilingual subjects to perform a decoding task, an encoding task, and a closed system thinking task which required attention and short-term memory. The experiments indicate that even in the absence of any obvious differences in the performance of a verbal task, the latent inferiority of information processing in the subjects' second language can be reflected in the decreased spare capacity in performing subsidiary tasks and in the increased effort which must be mustered in order to process the relevant information.

From the above research, speed of processing information is found to be related to language proficiency. Non-balanced bilinguals require more time in the second language than in the first to read the same amount of material. In this case, the fluent bilingual presents an opportunity to compare skilled and less skilled performance by the same individual. Such a comparision may provide an opportunity to study the speed of word recognition and memory span on different language systems and different levels of proficiency while avoiding the usual confounding factors due to individual differences.

1.2.12 Summary of literature review

Summarizing the literature review, a few important points deserve attention. It has been shown that word recognition and memory span are determinants of reading comprehension ability

in English. Studies reviewing the processing of Chinese and English indicate that there may be differences in the initial perceptual stage, but that similar linguistic techniques are implicated in the later stages. The grapheme-to-morpheme and grapheme-to-sound relationship within each Chinese character resembles the invariant spelling-to-sound relationship embedded in English orthography. These similarities in the processing of the

two writing systems are further substantiated by the cross-language experiments reviewed by Hung and Tzeng (1981). lt is reasonable to postulate that word recognition speed and memory span may be important factors affecting reading comprehension in both English and Chinese. However, there are two other factors that also need to be considered in studying Chinese-English bilingual readers: 1) the difference in processing speed between the first and second language, and 2) the difference between Chinese and English words in spoken duration. Direct comparisons between the two languages in terms of absolute items retained in memory span is probably not appropriate.

Chapter 2

Methodology

2.1 Statement of the problem

The general purpose of this study was to investigate whether memory span and word recognition play an important role in the different comprehension abilities among Chinese-English bilinguals.

The major research questions of the present study were therefore:

1. Is there any significant difference in the performance of bilingual readers on word recognition and memory span tasks in Chinese and English?
2. What are the relationships among word recognition, memory span and reading achievement in Chinese-English bilinguals?

2.2 Hypotheses

The following hypotheses were formulated:

Hypothesis 1

It was hypothesized that the accuracy rate of the lexical decision task would be related to the demand of a particular task.

Hypothesis 1 could be broken into :

1.1 Accuracy in lexical decision task would be significantly better in Chinese than in English, as Chinese was the

native language for both groups of readers.

1.2 Accuracy in physical matching of the lexical decision task would be significantly higher than name matching as it demands less capacity in processing.

Hypothesis 2

It was hypothesized that performance in lexical decision tasks was related to the demand of a particular task. Performance in physical matching would be better than name matching in terms of speed and accuracy in both languages because physical matching requires less capacity in processing.

Hypothesis 3

It was hypothesized that performance in lexical decision tasks was related to the linguistic characteristics of the language in which the task was performed.

Hypothesis 3 could be broken into :

3.1 Performance in physical matching would be better in terms of speed and accuracy in Chinese than in English for all groups due to the distinctive visual features of Chinese characters.

3.2 Latency differences between name matching and physical matching would be shorter in English than in Chinese due to the invariant spelling-to-sound relationship embedded in the English orthography.

Hypothesis 4

It was hypothesized that performance in the memory span tasks would be better in Chinese than in English for all groups because of the shorter duration in naming Chinese characters.

Hypothesis 5

It was hypothesized that performance differences between Chinese and English would be greater in non-balanced than in balanced bilinguals in both the lexical decision and memory span tasks. This is because balanced bilinguals are expected to process information with similar speed in both languages whereas non-balanced bilinguals would process Chinese at a faster rate than in English.

Hypothesis 6

It was hypothesized that for all groups of readers, the time taken for lexical decision would relate negatively to memory span performance and to reading skill in both Chinese and English, i.e., the faster the speed of identifying the words, the higher the score on memory span and on reading comprehension because of more capacity left over for the integration of materials and the storing of the final products.

Hypothesis 7

It was hypothesized that lexical decision latencies would depend on the level of proficiency in the language used.

Hypothesis 1 could be broken into:

7.1 The lexical decision latencies for balanced bilinguals would be shorter than for non-balanced bilinguals in the English version of the lexical decision tasks due to proficiency differences in the second-language whi affect decoding speed.

7.2 The difference in lexical decision latencies between balanced and non-balanced bilingual groups would not be significant in Chinese because of smaller differences in proficiency levels in the native language.

Hypotheses 8

It was hypothesized that lexical decision accuracy would depend on the level of proficiency in a language.

Hypotheses 8 could be broken down into :

8.1 The accuracy rate in English tasks would be higher in the balanced bilingual group than in the non-balanced bilingual group.

8.2 The accuracy rate difference in Chinese tasks between the balanced and non-balanced group would not be significant.

Hypothesis 9

It was hypothesized that performance in the memory span tasks would depend on the level of language proficiency.

Hypothesis 9 could be broken into :

9.1 The memory span in balanced bilinguals would be longer than that in non-balanced bilingual in the English version of the memory tasks. This was because non-balanced bilinguals were expected to be relatively inefficient in processing information in a second language which might result in reduced capacity for storing information.

9.2 The difference in memory span between the balanced and non-balanced bilingual groups would not be significant due to the fact that both groups demonstrate similar proficiency in their native language.

2.3 Rationale of the Experimental Tasks

Two experimental tasks were designed for the present study to investigate the performance of Chinese-English bilinguals on word recognition and memory span tasks. The first task was a lexical decision task and the second one was a word-span task. The rationale for employing these two tasks was based on a large body of evidence from reading research in English.

Word recognition performance can be assessed by asking subjects to make a non-verbal lexical decision on presented items. In this type of task, subjects are not required to give a verbal response and therefore might not be biased towards phonological coding. The non-verbal lexical decision task has an advantage over a vocalization task in that the latter may bias readers towards phonological coding and this bias is likely magnified with skilled

skilled readers (Haines and Leong, 1983). Frederikson (1978), Haines and Leong (1983), and Perfetti(1985) have all employed lexical decision tasks to demonstrate that word recognition ability differentiates skilled and less skilled readers.

Memory span is very often used to indicate working memory capacity. Many studies have been carried out to relate performance on memory span tasks to reading achievement (e.g. Torgesen, 1979; Torgesen and Houck, 1980). Individual differences in working memory capacity seem to be able to differentiate skilled from less skilled readers.

2.4 Stimuli

It has been shown in reading research that word length has an effect on immediate memory span (Baddley, Thomson and Buchanan, 1975; Ellis and Hennelly, 1980). In order to minimize the word length effect, all Chinese and English words used as stimuli were common nouns of only one syllable.

For the word span test, the Word Recall Test designed by Das and Naglieri (1985) was used. All words were easy-to-pronounce, one-syllable nouns, that did not rhyme.

2.5 Definitions

The major terms for the purpose of this study were defined as follows:

Word Recognition

Word recognition referred to the process of extracting information from printed characters through activating a location in the mental lexicon and as a result bringing semantic information into consciousness (Stanovich, 1982). Word recognition was operationally defined as: (1) the speed of making a lexical decision on a pair of printed words in terms of their physical appearance, (2) the speed of making a lexical decision on a pair of printed words in terms of their pronunciation.

Memory Span

Memory span performance involves the identification of items and the retention of order information. For the purpose of this study, memory span was operationally defined as the number of words correctly recalled by subjects from the Word Recall Test, either visually presented or orally presented.

Bilingual reader

Balanced bilingual readers are individuals who demonstrate a high level of reading comprehension in both their native and second languages. Non-balanced bilinguals are persons who have a better command of one language. In this study, a balanced bilingual was operationalized as an individual who performs equally well on reading comprehension tests in both Chinese and English. The balanced bilingual was a reader whose first and second language reading scores differed by

less than 10%. The term non-balanced bilingual was operationalized as a reader who performs better in Chinese than in English, as measured by reading comprehension tests in the native and second languages. The non-balanced bilingual would be one with a difference of more than 25% between the first- and second- language reading scores.

2.6 Experimental Design

Subjects

Chinese-English bilingual students within the age range of 19 to 24 , studying at the University of Alberta, were recruited for the experiment on a volunteer basis. All subjects were native speakers of Chinese, with Cantonese as their most fluent dialect. All subjects passed the Chinese Language test in the Hong Kong Certificate of Education Examination (similar to the high school Departmental Exam in the Province of Alberta). Eighty-four potential subjects, half of whom were male and half female, were screened using a Chinese comprehension test (The Hong Kong Certificate Examination Chinese Reading Comprehension paper, 1987) and an English comprehension test (The Hong Kong Advanced Level Examination English Language paper, 1987), which is equivalent to the A Level Exam in GCE, to obtain a measure of their reading proficiency level in each language. Both tests contain 25 multiple-choice questions.

15 balanced and 15 non-balanced bilinguals were retained as subjects, according to their performance on the reading tests. The mean scores for balanced and non-balanced bilinguals in the Chinese comprehension tests are 17.9 (S.D.=2.05) and 18.5 (S.D.=3.04) respectively. The mean score for balanced bilinguals in the English comprehension tests is 14.2 (S.D.=2.3) whereas that in non-balanced bilinguals is 7.7 (S.D.=2.05).

Apparatus and Procedure

Memory Span Task

The Word Recall Test designed by Das and Naglieri (1985), was used. Nine words which satisfied the following criteria were chosen: They are all one-syllable high-frequency nouns, which are easy to read aloud, do not rhyme, but vary in sound. The words were : book , key, bird, car, sun, dog, bat, shoe, and man.

Lists of words of increasing length from 4 to 9 items were given to the subjects on card booklets in the visual condition. Only one item was presented to subjects at a time. In the auditory condition, subjects were required to recall sets of individual word that had been presented to them orally. The number of words that had been correctly remembered in order by each subject were recorded in both conditions.

The modes of presentation of the visual and oral lists were counter balanced across subjects. The tasks were conducted in both Chinese and English in alternate order, and a practice trial

was given for each language before the actual recall test began. However, 11 rather than 9 items were included in the list due to the expected effect of shorter pronunciation duration of Chinese on memory span.

Lexical Decision Task

Lexical decision tasks were used to investigate the performance of bilingual readers. The tasks were adopted from Posner (Posner, 1973; Posner and Boies, 1971) and are presented in a paper-pencil form in both Chinese and English.

The first task was a physical matching task. The page contained 200 items; 50 signal items and 150 item distractors. Signals were two physically identical words (physical-same) e.g. the words 'DAY,DAY'. Distractors were either two physically different words, e.g. 'day bar', or two lexically different words, one capital one small (e.g. DAY day, DAY bar). For the Chinese version, distractors were either two physically different words, e.g. 宝,牀,or two lexically different words, one simplied, one complex e.g. 床,牀

The second task was a name matching task. The 50 signal items were word pairs that had the same name, e.g. 'DAY day, day day'. The 150 distractors were either two physically different words, such as 'day bar' or two lexically different word, one capital one small (e.g. DAY bar). The Chinese version contained distractors which were either 1) different physically and

phonologically ,or 2) different lexically i.e. one simplied and one complex, with different name, e.g. 宝,喫.

Subjects were given practice trials before doing each of the actual tasks. Instructions were given to subjects to cross out signal items with pencils and to penform the tasks from left to right, from top to bottom. The order of presentation of the two tasks was counter-balanced across subjects. The amount of time required for each subject to finish a task was measured with a stop watch and recorded.

2.7 Dependent and Independent Variables

The memory span tasks (auditory and visual) , lexical decision tasks (name matching and physical matching), bilingual skills (balanced, non-balanced) and languages (Chinese and English) were treated as independent variables in this experiment, whereas the reaction time and number of words recalled were the dependent variables.

Chapter 3

Results and Intrepretation

The scores on word recognition tasks were analysed with two separate repeated measures ANOVAs, one for the accuracy data and one for the latency data.

3.1 Accuracy of Word Recognition

The accuracy data for word recognition performance were subjected to a 2 (type of reader) X 2 (type of task) X 2 (type of language) analysis of variance with the last two factors repeated. For each subject, the accuracy was calculated for name matching and physical matching in both Chinese and English. Table 1 shows the means and standard deviations of the accuracy rate for the subjects by type of reader, task and language. The means of accuracy rate for the two groups are illustrated graphically in Figure 1. The results of the ANOVA are presented in Table 2.

A significant main effect for language was observed, $F(1,28)=5.569$, $P < .05$. The main effect showed that performance in Chinese word recognition tasks was significantly more accurate than in English word recognition tasks. The mean accuracy rates for Chinese word recognition tasks and English word recognition tasks were 96.6% and 94.3% respectively. A significant main effect for type of task was also observed, $F(1,28)=14.2$, $P < .05$. The main effect indicated that physical matching had a higher accuracy rate than name matching. The mean accuracy rate

Table 1

Means and Standard Deviations for Word Recognition Accuracy Rates

Bilingual ability		English		Chinese	
		Physical matching	Name matching	Physical matching	Name matching
Balanced	X	97.3%	93.5%	97.6%	96.8%
		(5.5%)	(8.8%)	(6.1%)	(3.4%)
Non-balanced	X	96.1%	90.4%	97.6%	94.3%
		(5.3%)	(7.3%)	(7.1%)	(5.1%)

Table 2

Summary of ANOVA for Word Recognition Accuracy involving 2 (Type of reader) X 2 (Type of language) X 2 (Type of task)

Source	D.F.	M.S.	F	P
Between Subjects				
A (Type of reader)	1	22.559	1.115	0.300
Error	28	20.232		
Within				
B (Language)	1	38.555	5.569	0.024*
B X A	1	1.172	0.172	0.681
Error	28	6.813		
C (Task)	1	90.176	14.20	0.001**
C X A	1	8.496	1.338	0.257
Error	28	6.35		
C X B	1	13.3	2.356	0.136
C X B X A	1	0.176	0.031	0.861
Error	28	5.65		

*significant at .05

** significant at .01

N = 30

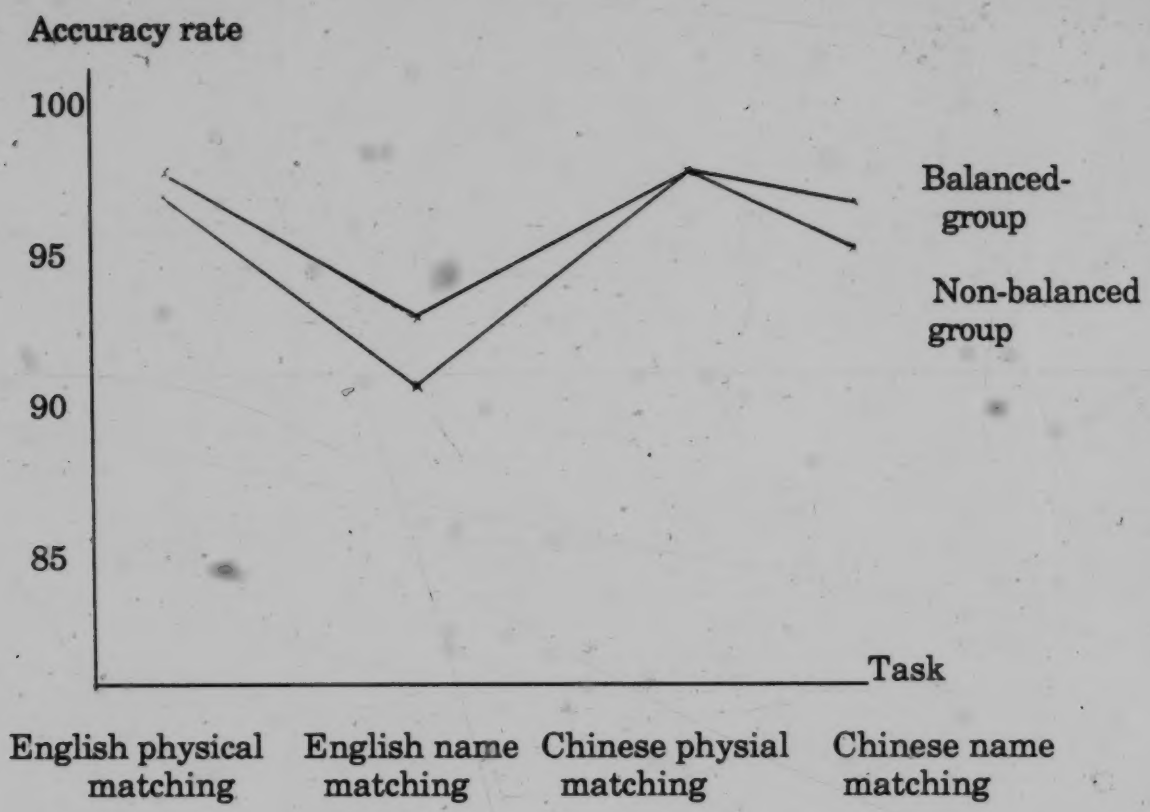

Figure 1. Means of word recognition accuracy rate for balanced and non-balanced bilinguals as a function of language and task.

was 97.2% for physical matching and 93.7% for name matching. No significant interaction effect was observed.

Integrating the results, the main effect for language gave support to Hypothesis 1.1 which predicted that accuracy in the word recognition task would be higher in Chinese than in English. As revealed in the previous analysis, the advantage of using Chinese in word recognition tasks was indicated in both physical and name matching. Hypothesis 1.1 was therefore supported. The main effect for type of task also support Hypothesis 1.2 which predicted that accuracy in physical matching in the word recognition task would be significantly higher than name matching.

In sum, the results of word recognition accuracy revealed that accuracy rate of the word recognition tasks were related to the demands of the particular task. Tasks that required less capacity to process tended to have higher accuracy rates. The superiority of the native language (Chinese) and physical matching over the second language (English) and name matching was shown.

3.2 Word Recognition Latency

The word recognition latency data were subjected to a 2 (type of reader) X 2 (Type of language) X 2 (type of task) analysis of variance with the last two factors repeated. Table 3 presents the means and standard deviations of the word recognition latency by

type of reader, type of langage, and type of task. The means are graphically illustrated in Figure 2. Table 4 shows the results of the ANOVA for the data.

A significant main effect for language was observed, $F(1,28)=13.943$, $P < .01$. The main effect for language indicated that word recognition in English was significantly faster than in Chinese. The mean word recognition latency was 131.11 seconds for English and 140.47 seconds for Chinese. The main effect for type of task was also significant , $F(1,28)=238.28$, $P < .01$. The mean latencies for physical matching was shorter than that for name matching. The main effects for language and task were significant. However, these results should be interpreted in light of the significant interaction between the variables.

A significant language by task interaction was observed, $F(1,28)=49.85$, $P < .01$ and depicted graphically in Figure 3. The significant interaction between language and task appeared to be due to the greater increase in word recognition latency on name matching for Chinese relative to English. To further determine specific differences, a T-test was used to compare the word recognition latency means of the two types of task and the two kinds of languages. Table 5 shows the results of this post-hoc analysis. Results showed that the word recognition latency differences between the two kinds of task were significant for both Chinese and English. Latency of Chinese physical matching was shorter than that of name matching regardless of language. A second T-test comparing the latency means of the two kinds of

Table 3

Means and Standard Deviations for Word Recognition Latencies (Sec)

	English		Chinese	
Bilingual ability	Physical matching	Name matching	Physical matching	Name matching
Balanced X	113.8	148.5	108.1	174.9
	(22.9)	(34.7)	(23.6)	(26.5)
Non-balanced X	111.4	150.7	104.9	174.0
	(20.0)	(24.4)	(15.1)	(32.5)

Table 4

Summary of ANOVA for Word Recognition Latency Data involving 2 (Type of reader) X 2 (Type of language) X 2 (Type of task)

Source	D.F	M.S.	F	P
Between Subjects				
A (Type of reader)	1	372.4	0.019	0.891
Error	28	195243.0		
Within				
B (Language)	1	263424.00	13.943	0.001**
B X A	1	2764.80	0.146	0.705
Error	28	18892.80		
C (Task)	1	8264832.0	238.28	0.001**
C X A	1	9062.4	0.261	0.613
Error	28	34685.8		
C X B	1	719001.6	49.85	0.001**
C X B X A	1	1036.8	0.072	0.791
Error	28	14422.3		

** significant at .01

N = 30

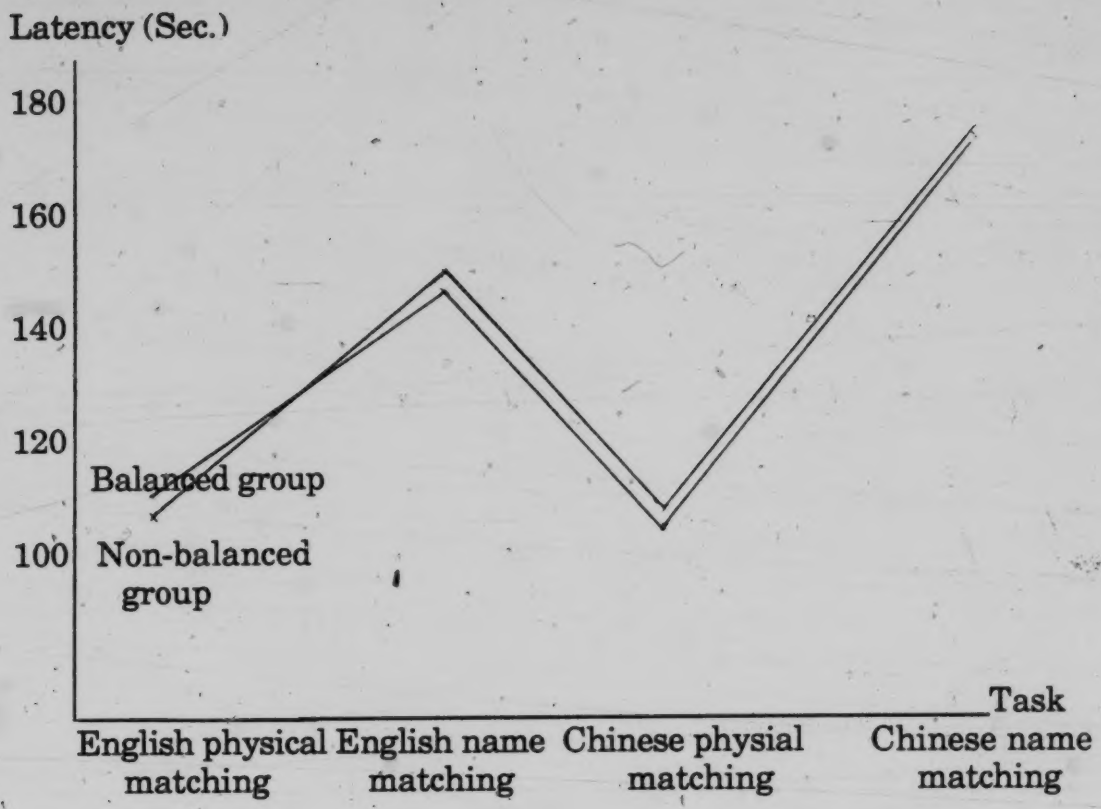

Figure 2. Means of word recognition latency rate for balanced and non-balanced bilinguals as a function of language and task.

task in both Chinese and English was performed. The word recognition latency mean differences between Chinese and English task were significant. Mean differences between English physical matching and Chinese physical matching was significant, $T(1,29)=2.41$, $P < .05$. Moreover, mean differences between English name matching and Chinese name matching was also significant, $T(1,29)=-6.4$, $P < .001$. These results indicated that both language and task factors contribute significantly to the interaction effects in Figure 3.

The above word recognition latency analysis support Hypothesis 2 stating that latency in physical matching would be shorter than name matching. The results showed that overall word recognition latency in physical matching was significantly shorter than name matching regardless of language. Although the word recognition latency difference between Chinese and English was not very great, the difference was significant. Physical matching in Chinese required a shorter recognition latency than that in English. Hypothesis 3.1 which stated that latency in Chinese physical matching would be shorter than English physical matching was thus supported. Hypothesis 3.2 also received support from these results. The latency difference between Chinese name matching and English name matching was significant. Latency in English name matching was much shorter than that in Chinese.

In short, the findings of word recognition latency demonstrated that language and task appeared to be the crucial factors affecting performance in recognizing words. Performance

in Chinese word recognition was superior to English word recognition, and in turn, physical matching was superior to name matching in terms of recognition latency.

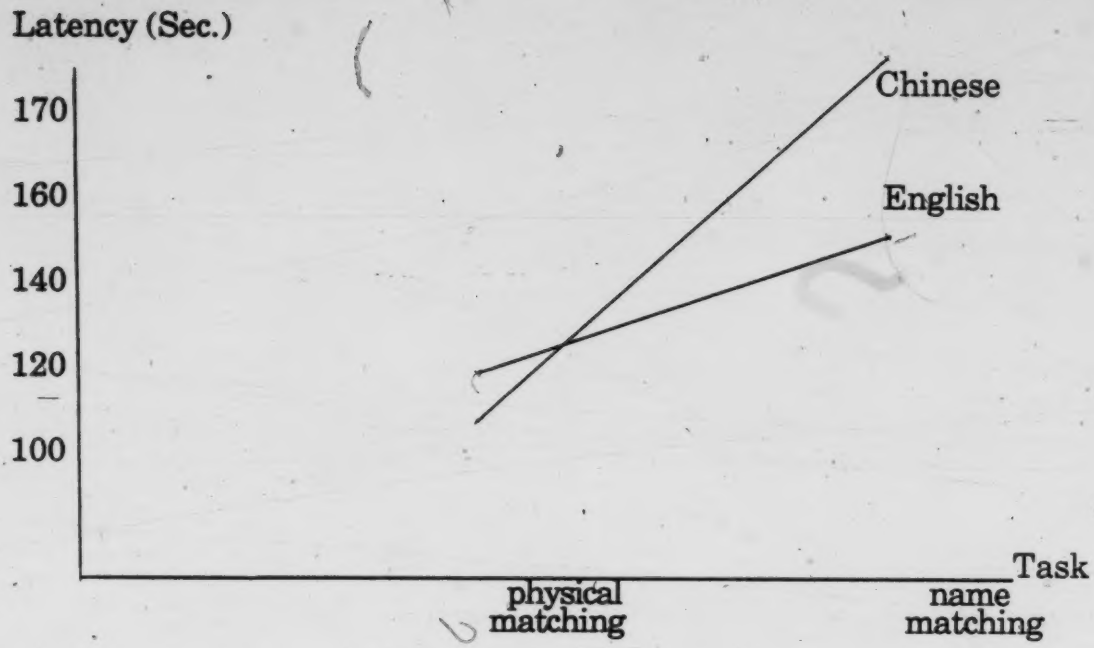

Figure 3. Means of word recognition latency as a function of language and task.

Table 5

Results of T-test on means of Word Recognition Latencies (Sec) involving different tasks and languages

Task	D.F	T value	P
Physical matching			—
Chinese			
English	29	2.41	0.023*
Name matching			
Chinese			
English	29	-6.40	0.0001**
Language			
English			
Physical			
Name matching	29	-10.44	0.0001**
Chinese			
Physical			
Name matching	29	-15.48	0.0001**

*significant at .05

** significant at.001

N = 30

3.3 Memory Span Task

The memory span data were subjected to a 2 (type of reader) X 2 (type of language) X 2 (mode of presentation) analysis of variance with the last two factors repeated. Table 6 shows the means and standard deviations of memory span for the two groups and Figure 4 presents the means graphically. Table 7 shows the results of the ANOVA.

There was a highly significant main effect for language, $F(1,28)=340.867$, $P < .01$. The main effect for language revealed that memory span for Chinese was significantly longer than English. The mean memory span was 6.283 for English and 8.983 for Chinese. Memory span for Chinese was 2.7 longer than English.

A significant language by task interaction was observed, $F(1,28)=5.334$, $P < .05$. The interaction is depicted graphically in Figure 5. To determine specific differences, the T-test was performed between Chinese and English means of the two presentation modes. Results in Table 8 shows that the memory span differences between the two languages were highly significant ($P < .001$) for both auditory and visual modes of presentation. Within the auditory mode and the visual mode, language was the crucial factor in memory span performance. Memory span for Chinese was longer than English regardless of mode of presentation. Hypothesis 4 which stated that performance in memory span tasks would be better in Chinese than English thus received support.

In sum, language seemed to be an important factor affecting performance in memory span. Memory span in Chinese was significantly longer than memory span in English.

Table 6

Means and Standard Deviations for Memory Span Tasks

Bilingual ability		English		Chinese	
		Auditory memory	Visual memory	Auditory memory	Visual memory
Balanced	X	6.5	6.8	9.1	8.9
		(0.92)	(1.3)	(1.2)	(1.5)
Non-balanced	X	5.7	6.1	9.1	8.8
		(0.8)	(1.1)	(1.4)	(1.5)

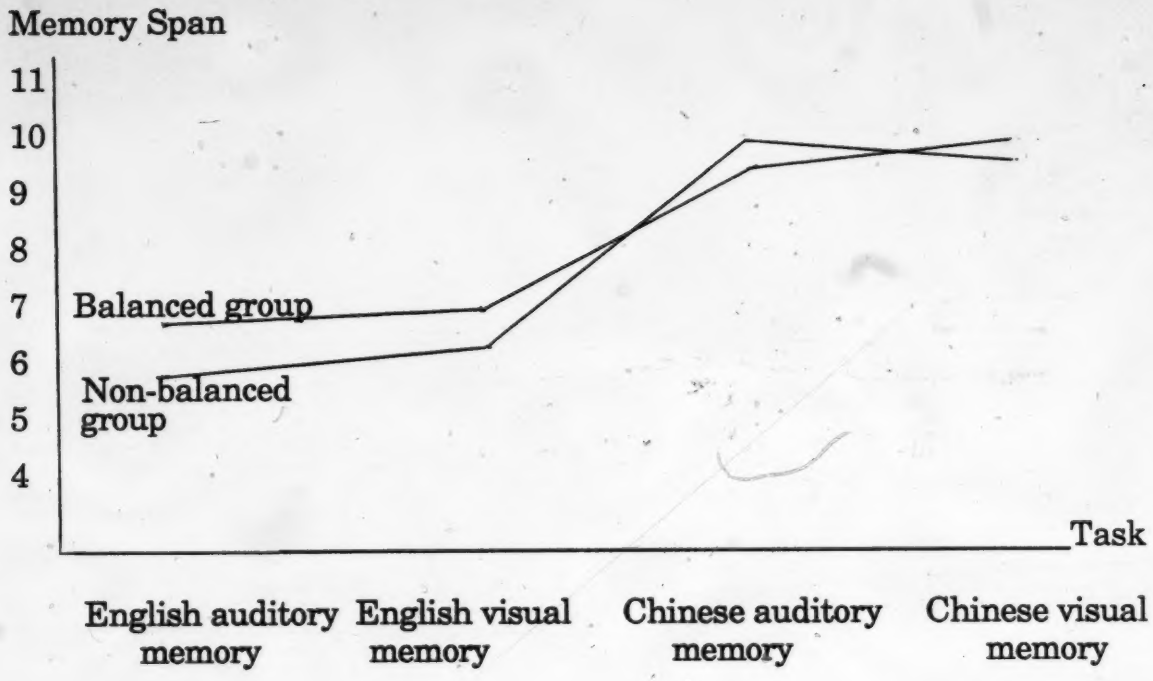

Figure 4. Means of memory span for balanced and non-balanced bilinguals as a function of language and mode of presentation.

Table 7

Summary of ANOVA for Memory Span Data involving 2 (Type of reader) X 2 (Type of language) X 2 (Mode of presentation)

Source	D.F	M.S.	F	P
Between Subjects				
A (Type of reader)	1	4.032	1.109	0.301
Error	28	3.637		
Within				
B (Language)	1	218.70	340.87	0.001**
B X A	1	3.333	5.194	0.030
Error	28	0.642		
C (Presentation)	1	0.132	0.086	0.771
C X A	1	0.037	0.024	0.878
Error	28	1.530		
C X B	1	2.699	5.334	0.029*
C X B X A	1	0.135	0.268	0.609
Error	28	0.506		

** significant at .01

** significant at .05

N = 30

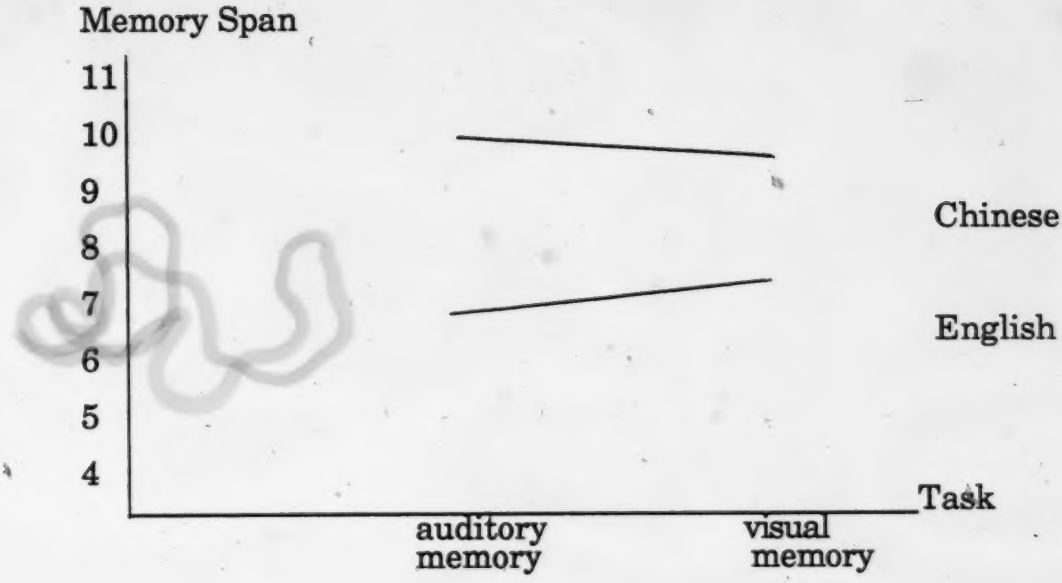

Figure 5. Means of memory span as a function of language and task.

Table 8

Results of T-test on means of Memory Span Task as a function of language

Task	D.F	T value	P
Auditory Memory Task			
Chinese			
English	29	-14.35	0.0001*
Visual Memory Task			
Chinese			
English	299	-12.29	0.0001*

*significant at .001

N = 30

3.4 Difference Between Chinese and English Task in balanced and Non-balanced Bilinguals

In order to compare the difference between Chinese and English tasks between the balanced and non-balanced bilinguals, a T-test was performed. The difference between the Chinese and English tasks was computed for each subject by subtracting the scores on the Chinese task from those on the English task (Table 9). Differences in name matching, physical matching, auditory memory and visual memory between the two groups were subjected to T-tests. Results are shown in Table 10.

Comparing the results of the two groups, only one difference between means was found to be significant. This was the mean difference between Chinese and English auditory memory task, $T(1,28)=2.1$, $P=.05$. The difference between the performance in Chinese and English was greater for the non-balanced bilinguals than for the balanced bilinguals. Although both groups performed better in their native language, balanced bilinguals performed relatively better than the non-balanced bilinguals in their second language.

In view of this analysis showing no significant group difference for the means for memory span, the significant difference found in the T-test was probably due to the language effect within the balanced and non-balanced bilingual groups. As illustrated in Figure 4, non-balanced bilinguals' performance in English memory span

Table 9

Means and Standard Deviations for Difference between Chinese and English Task of Balanced and Non-balanced bilinguals

Variable	Number of Cases	S.D.	Mean
Difference in name matching(Sec)			
Balanced group	15	-28.4	24.8
Non-balanced group	15	-23.3	14.8
Difference in physical matching(Sec)			
Balanced group	15	5.7	13.7
Non-balanced group	15	6.5	14.6
Difference in auditroy memory(no.)			
Balanced group	15	-2.6	0.91
Non-balanced group	15	-3.4	1.20
Difference in visual memory(no.)			
Balanced group	15	-2.133	0.915
Non-balanced group	15	-2.667	1.175

Table 10

Results of T-test on difference between Chinese and English Tasks between balanced and non-balanced bilinguals

Varriable	D.F	T value	P
Difference in name matching(Sec)			
balanced			
non-balanced	28	-0.39	0.697
Difference in physical matching(Sec)			
balanced			
non-balanced	28	-0.15	0.886
Difference in auditory memory(no.)			
balanced			
non-balanced	28	2.10	0.050*
Difference in visual memory(no.)			
balanced			
non-balanced	28	1.39	0.176

*significant at .05

N = 30

was lower than balanced bilinguals whereas performance in Chinese did not differ significantly for both groups. Since only the difference in Chinese and English auditory memory task between the two groups was significant, Hypothesis 5 which stated that performance differences between Chinese and English would be greater in non-balanced than in balanced bilinguals in both the word recognition and memory span task received only partial support.

3.5 Relationship between Word Recognition, Memory Span and Reading Comprehension

It was predicted in Hypothesis 6 that there would be a negative relationship for both of the two languages between word recognition latency and comprehension score. It was also predicted that there would be a positive relationship between memory span and comprehension scores. Pearson product-moment correlation coefficients computed for the Chinese tasks for all subjects are presented in Table 11. Table 12 presents the correlations for the Chinese task for balanced and non-balanced bilinguals separately. Correlations for the English task of all subjects are presented in Table 13 whereas Table 14 shows separate correlations for each group.

It can be seen from Table 11 and Table 12 that word recognition latency and memory span were significantly correlated with reading comprehension. Chinese word recognition latency was

Table 11

Correlation among Chinese Word Recognition Latency, Chinese Memory Span and Chinese Reading Comprehension

	CWR	C M	CR
Chinese word recognition(CWR)	1.00		
Chinese memory(CM)	-0.231	1.00	
Chinese reading comprehension(CR)	-0.360*	0.322*	1.00

* significant at .05
N = 30

Table 12

Correlation among Chinese Word Recognition Latency, Chinese Memory Span and Chinese Reading Comprehension for Balanced and Non-balanced Bilinguals

	CWR	C M	CRC
Chinese word recognition(CWR)	1.00		
Chinese memory(CM)	0.0763 (-0.505)*	1.00	
Chinese reading comprehension(CRC)	-0.541* (-0.176)	0.348* (0.379)*	1.00

a. results for non-balanced bilinguals are in bracket
* significant at .05
N = 30

negatively related to Chinese reading comprehension (r=-0.36, P < .05). Breaking down the recognition task into name matching and physical matching revealed that Chinese name matching was mainly responsible for the significant negative correlation between Chinese word recognition latency and Chinese reading comprehension (r=-0.410, p < .05).

As shown in Table 12, the negative correlation between Chinese word recognition latency and Chinese reading comprehension was moderately high in balanced bilingual, r=-0.541, P < .05. The results in Table 13 also show a negative correlation between English word recognition and English reading comprehension for all subjects, r=-0.348, P < .05. Separating the word recognition tasks into name matching and physical matching, it indicated that English name matching was the main factor affecting the correlatio , r=-0.489, p < .05 for balanced bilingauals and r=-0.611, p < .01 for non-balanced bilinguals) Separate analyses as indicated in Table 14 revealed negative correlations for balanced bilinguals, r=-0.558, P < .05 and higher negative correlation for non-balanced bilinguals, r=-0.608, P < .05. The negative correlation indicates that the shorter the time required to process words, the more likely one would obtain a higher score in the reading comprehension test. The relationship between word recognition latency and reading comprehension was found in both Chinese and English. Name matching seemed to be a crucial factor that relates to reading comprehension.

In addition, memory span was correlated with reading comprehension (Table 11 and Table 13). Chinese memory span correlated with Chinese reading comprehension, r=0.322, P < .05 whereas English memory span correlated with English reading comprehension, r=0.5, P < .05. Memory span was positively related to reading comprehension for both languages. Individuals having relatively long memory span tended to score high in the reading comprehension test.

The relationship between memory span and word recognition latency was not significant when the two groups were combined in the analysis. However, separate analysis for each group did reveal some significant correlations. Although not every one of the correlations in Table 12 and 14 was significant, most of them showed a negative sign. Significant negative correlation exists between Chinese word recognition and Chinese memory span (r=-0.505, P < .05) for non-balanced bilinguals. This result offers partial support for the relationship between memory span and word recognition.

In sum, evidence was found for Hypothesis 6 which stated that for all groups of readers, the time taken for word recognition will relate negatively to memory span performance and reading skill in both Chinese and English. Word recognition latency (especially for name matching) and reading comprehension was negatively correlated for both Chinese and English. Memory span was also negatively correlated with word recognition latency for Chinese and English in the non-balanced bilingual group. Moreover, memory span was found to have a significant positive relationship with

reading comprehension for both languages. Thus, Hypothesis 6 seemed to be supported.

Table 13

Correlation among English Word Recognition Latency, English Memory Span and English Reading Comprehension

	EWR	EM	ECR
English word recognition(EWR)	1.00		
English memory(EM)	-0.172	1.00	
English reading comprehension(ERC)	-0.348*	0.510*	1.00

* significant at .05
N = 30

Table 14

Correlation among English Word Recognition Latency, English Memory Span and English Reading Comprehension of Balanced and Non-balanced Bilinguals

	EWR	EM	ERC
English word recognition(EWR)	1.00		
English memory(EM)	0.091 (-0.252)	1.00	
English reading comprehension(ERC)	-0.558* (-0.608)*	0.500* (0.195)	1.00

a. results for non-balanced bilinguals are in bracket
* significant at .05
N = 15

Chapter 4
Discussion and implications

The primary objective of this research was to investigate the relationship among rapid, automatic recognition of context-free word, memory span, and reading comprehension in Chinese-English bilinguals. In this chapter, a summary of the obtained results are presented and discussed in terms of the purpose of this study and in relation to the theoretical and practical issues. Following the discussion, a number of suggestions and implications are outlined for future research and reading instruction.

Summary of results

The results of the study indicate that there are significant differences between the performance of bilingual readers in Chinese and English word recognition tasks. Latency in Chinese physical-matching tasks was shorter than in English physical-matching tasks. However, the opposite result was found in name-matching, where the latency in English name-matching was shorter than in Chinese name-matching. In addition to the effect of language type on word recognition performance, the task factor also influences reaction time. Physical-matching was found to have a shorter latency than name-matching in both languages. Latency in Chinese physical-matching was the shortest among the four recognition tasks and Chinese

name-matching was the longest.

A further result of this study is that there are significant differences in accuracy on the word recognition tasks. Peformance on Physical-matching tasks was found to be more accurate than on name-matching tasks and Chinese word recognition was more accurate than English word recognition for both physical-matching and name-matching tasks.

Taking both speed and accuracy into consideration, the findings suggest that there is no trade-off between speed and accuracy. Tasks that require less time to perform tend to be performed more accurately (i.e. physical-matching tasks). Moreover, the superiority of an individuals' native language over the second language is evident. Performance in Chinese word recognition was more accurate than in English. Chinese physical-matching was faster and more accurate when compared to English and even though latency in Chinese name-matching was longer than in English, performance in Chinese was still superior in terms of accuracy.

The findings of this study also indicate that there are significant differences between performance in the Chinese and English memory span tasks. Chinese memory span was consistantly longer than English memory span regardless of the mode of presentation. Non-balanced bilinguals were found to have a greater discrepancy between their performance on Chinese and English auditory memory span tasks than balanced-bilinguals.

Finally, the correlation between word recognition latency

and reading comprehension indicates that processing speed is a crucial source of individual variation in comprehension. This relationship is true for both Chinese and English. A further source of variability in reading comprehension appears to be memory span, which correlates positively with reading comprehension in both languages. Individuals who scored high on the reading test tended to have a longer memory span in both languages. Futhermore, the correlation between word recognition and memory in non-balanced bilinguals suggests that individuals who have shorter word recognition latency also have better memories.

General discussion

These findings are in agreement with the working memory model, which suggests that there is a trade-off between the processing and storage functions of memory. The results are also consistent with current theories of reading (LaBerge & Samuels,1974; Lesgold & Perfetti, 1978). It is generally agreed that reading comprehension requires both lower-level processes (e.g. word recognition) and higher-level processes (e.g. integration of sentences). If less capacity is devoted to the lower-level processes, then more attention can be allocated to higher- level processes. In other words, faster word recognition speed frees more attentional resources for storage and higher level activity. Thus, a faster rate of word recognition is crucial to proficient reading comprehension.

The negative correlation between word recognition and

reading comprehension indicates that the faster the word recognition speed, the better the reading comprehension. Reading comprehension, regardless of language, depends on the efficiency of processing rather than a static memory capacity. Another finding that is related to word recognition and comprehension is that a task that clearly does not require much memory access has no apparent relationship with reading comprehension. Physical-matching, which demands less processing and memory access, does not correlate with comprehension as much as name-matching does. This result is consistent with the findings of Jackson (1980).

Within the working memory model, speech-based materials are stored according to their acoustic properties in the articulatory loop. Therefore, different languages should affect working memory differently according to their acoustic characteristics. Chinese characters are monosyllabic and have been found to require a shorter articulation time than English words (Hoosain,1984). Since memory span for words is a simple function of their spoken duration, memory span in Chinese has been found to be relatively longer than in English (Baddeley, Thomson & Buchanan, 1975; Hoosain, 1984; & Stigler & Lee, 1986). The present results are consistent with the working memory model and previous research findings that pronunciation duration is crucial in memory span performance. Language characteristics not only affect memory span, they also affect processing speed. In this study, latency in English name-matching was found to be

shorter than Chinese. The invariant spelling-to-sound relationship embedded in the English orthography seems to be a likely explanation for the differences.

Besides the language effect, inter-lingual proficiency also influences the processing of words and memory span performance. Ehri and Wilce (1979,1983) suggest that, based on the LaBerge and Sammuals automaticity model, the attainment of word recognition skill can be analysed into three phases : accuracy, automaticity, and speed. Although word recognition latency in Chinese (first language) did not show a superiority effect over English (second language) in this study, the advantage of Chinese manifested itself in higher accuracy. Bilinguals are more efficient in processing information in their first language than in their second language in terms of the quality of performance. The results of the memory span tasks also provide evidence suggesting that language proficiency is an important source of individual differences in working memory. Non-balanced bilinguals showed more discrepancy between their performance in Chinese and English auditory memory tasks than balanced-bilinguals. Although both groups showed better performance in Chinese than in English, non-balanced bilinguals indicated a greater efficiency in using Chinese over English in the auditory memory tasks when compared to the balanced bilinguals. This suggests that non-balanced bilinguals are less efficient in memorizing words in their second language. It supports the idea that second language operations require more processing capacity or resources than do

first language operations for non-balanced bilinguals whose second language is less proficient than their first language (Dornic,1980; Favreau and Sagalowitz, 1980,1983; & Standing, Smith and Isely,1980).

The visual memory span task did not produce significant differences between Chinese and English amongst the non-balanced bilinguals in this study. One explanation could be that visual coding is used to a greater degree in reading Chinese words. Since reading involves having to encode visual symbols into phonological codes in order to maintain them in the articulatory loop, the lack of grapheme-phoneme correspondence in the Chinese language requires a relatively longer naming time when compared to English words. As a result, the difficulty in naming Chinese words affects the efficiency of using the native language for memorization purposes and consequently Chinese visual memory does not show much advantage over English visual memory. The finding that Chinese name-matching tasks took longer to perform than English name-matching is consistent with this postulation.

There is also no indication from the results of this study that intra-lingual proficiency affects either speed or accuracy in the performance of English word recognition tasks. Non-balanced bilinguals who are weaker in English do not differ significantly in English word recognition speed or accuracy from balanced bilinguals whose processing proficiency is similar in both languages. One reason for this could be that since the stimuli used

for this study were all high frequency words, and the subjects who participated were university students, it is possible that both balanced and non-balanced bilinguals have reached a similar level of proficiency in word recognition for high-frequency words. However, the problem of whether non-balanced bilinguals have attained all three phases for low-frequency words is still an issue.

Still another explanation can be drawn from the work of Dornic (1980) which suggests that for many bilinguals there is less spare processing capacity available when they are working in the second language. The inferiority of information processing in an individual's second language may not be obvious in terms of speed and accuracy but it can be reflected in the decreased spare capacity in performing subsidiary tasks and in the increased effort which must be mustered in order to process the relevant information. Since reading requires both higher-level and lower-level processing, efficiency in lower-level processing does not guarantee good comprehension. Non-balanced bilinguals may have attained the speed and accuracy levels for simple word recognition, but their poorer comprehension may be a reflection of the decreased spare capacity that is needed to perform higher level tasks such as the integration of sentences and the extraction of meanings from text. This consequently hinders reading comprehension.

Limitations of the study and implications for future research

The present study indicates that there are few significant

differences between balanced and non-balanced bilinguals in word recognition. This finding is unexpected but understandable. For one thing, this study used only Chinese-English bilingual university students, all of whom were proficient in their second language (English). Although non-balanced bilinguals are comparatively weaker in their second language, their reading skill still allow them to function at a university level. Thus, the difference between the proficiency levels in Chinese and English in non-balanced bilinguals might not be great enough to detect in their processing speed in the word recognition tasks. It would be of interest to extend the present study to more extreme non-balanced bilinguals and to languages other than Chinese and English in an attempt to gain further insights into the nature of individual differences in word recognition skills.

Another factor that may have affected the results is the selection of stimulus materials. The words which were used may have been too high frequency to be used to discriminate between the performances of skilled and less skilled readers. It might be useful if low frequency words were used to further investigate the issue in future research. Also, name-matching ability was found to be a more potent variable in predicting reading comprehension than physical-matching ability. This indicates that word recognition tasks which require more processing are a better predicter of reading comprehension ability than tasks that do not demand much in the way of processing. Thus, incorporating tasks that demand more processing in future research might be more

fruitful in the investigation of individual differences. In addition to the stimulus words employed in the study being high frequency words, they were also single character words. Such single character words make up a small proportion of Chinese words and are not as common as words of two characters. It is recommended that future research should further explore the issue by extending the research paradigm to two-character words.

By investigating the performance of a group of bilingual readers in word recognition, memory span, and reading comprehension, the present study confirms that the relationships among these three variables hold true across the alphabetic and logographic writing systems. Word recognition and memory span are crucial in reading in Chinese as well as in English.

A major implication for reading practice is the necessity to train learners of a new language to be both fast and accurate at recognizing and memorizing words if fluent reading is to be attained. However, the above suggestion does not imply that merely practicing rapid word recognition will naturally result in better reading comprehension. This is evident in the performance of non-balanced bilinguals in English word recognition tasks, where the tasks cannot differentiate skilled and less skilled readers of English. This indicates that besides fast word recognition, higher-level processing such as planning and hypothesis-testing are also important in reading at a high level. It is possible that fast word recognition is necessary to free more processing space for higher cognitive processes to operate efficiently so as to benefit

reading comprehension.

Bilingual research in reading not only allows investigation in studying the speed of word recognition and memory span at different levels of language proficiency, it also provides opportunities to investigate the study of human linguistic information processing in two different language systems. Further studies of bilingual reading will probably provide greater insight into the understanding of the reading process and related information processing.

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Appendix A : Name matching

HOT hot	PEN BAR	BAR day	MAP HOT	day hot
bar PEN	map map	DAY day	PEN hot	BAR HOT
hot HOT	BAR PEN	day BAR	HOT MAP	HOT hot
pen PEN	DAY map	bar DAY	hot PEN	HOT BAR
HOT PEN	PEN bar	BAR day	DAY map	map MAP
day PEN	bar HOT	BAR pen	DAY day	map BAR
HOT hot	PEN BAR	BAR day	map hot	hot day
PEN pen	MAP pen	DAY bar	PEN hot	BAR HOT
HOT pen	bar MAP	DAY day	hot pen	hot bar
BAR HOT	PEN HOT	MAP day	map BAR	PEN hot
HOT hot	bar pen	DAY bar	HOT pen	hot bar
bar hot	HOT pen	BAR day	map map	PEN hot
HOT hot	bar pen	bar DAY	MAP hot	HOT day
bar MAP	DAY day	PEN PEN	hot BAR	pen DAY
pen hot	BAR pen	DAY bar	MAP day	map MAP
bar hot	pen HOT	day BAR	MAP DAY	PEN pen
hot HOT	pen bar	bar day	map hot	HOT hot
hot HOT	BAR PEN	day BAR	HOT MAP	bar hot
pen PEN	map map	bar DAY	hot PEN	HOT BAR
HOT PEN	PEN bar	BAR day	DAY map	map MAP
day PEN	bar HOT	pen HOT	DAY day	map BAR
HOT hot	PEN BAR	BAR day	map hot	hot HOT
BAR HOT	PEN HOT	DAY day	map BAR	PEN hot
HOT hot	bar pen	DAY bar	HOT pen	hot bar
pen PEN	map map	bar DAY	hot PEN	HOT BAR
bar MAP	DAY day	PEN PEN	hot BAR	pen DAY
hot HOT	pen bar	bar day	map hot	HOT hot
day PEN	bar HOT	pen pen	DAY day	map BAR
HOT map	MAP MAP	MAP hot	BAR hot	MAP HOT
MAP HOT	HOT pen	hot BAR	MAP BAR	bar map
PEN hot	day day	hot day	bar pen	MAP DAY
bar pen	bar DAY	MAP hot	HOT day	BAR map
pen PEN	map map	bar DAY	hot PEN	HOT BAR
bar MAP	DAY day	PEN PEN	hot BAR	pen DAY
HOT hot	bar pen	bar DAY	MAP hot	HOT day
bar MAP	DAY day	PEN PEN	hot BAR	pen DAY

pen hot	BAR pen	DAY bar	MAP day	map MAP
bar hot	pen HOT	day BAR	MAP MAP	PEN pen
hot HOT	pen bar	bar day	map hot	HOT hot
bar hot	HOT pen	BAR day	map map	BAR pen

Physical matching

HOT hot	PEN PEN	BAR day	MAP HOT	hot hot
bar PEN	map map	DAY day	PEN hot	BAR HOT
hot HOT	BAR PEN	BAR BAR	HOT MAP	HOT hot
pen PEN	map map	bar DAY	hot PEN	BAR bar
HOT PEN	PEN bar	BAR day	DAY map	MAP MAP
DAY DAY	bar HOT	pen pen	DAY day	map BAR
HOT hot	PEN BAR	BAR day	map hot	hot Hot
PEN pen	MAP MAP	DAY bar	PEN hot	BAR HOT
HOT pen	bar MAP	day day	hot pen	bar bar
BAR HOT	PEN HOT	MAP day	map BAR	PEN hot
HOT hot	pen pen	DAY bar	HOT pen	bar bar
bar hot	HOT HOT	BAR day	map map	PEN hot
HOT HOT	bar pen	bar DAY	MAP hot	HOT day
bar MAP	DAY day	PEN PEN	hot BAR	pen DAY
pen hot	BAR pen	DAY DAY	MAP MAP	map MAP
bar hot	pen HOT	day BAR	MAP DAY	PEN pen
HOT HOT	pen bar	bar day	map hot	hot hot
hot HOT	BAR PEN	day BAR	HOT MAP	bar hot
pen PEN	map map	bar DAY	hot PEN	HOT BAR
HOT PEN	PEN bar	BAR BAR	DAY map	MAP MAP
day PEN	bar HOT	pen pen	DAY day	map BAR
HOT hot	PEN BAR	BAR BAR	map hot	hot HOT
BAR BAR	PEN HOT	day day	map BAR	PEN PEN
hot hot	bar pen	DAY bar	pen pen	hot bar
pen PEN	map map	bar DAY	hot PEN	HOT BAR
bar MAP	DAY day	PEN PEN	hot BAR	pen DAY
hot HOT	pen bar	bar day	map hot	HOT hot
PEN PEN	bar HOT	pen pen	DAY day	BAR BAR
HOT map	MAP MAP	MAP hot	BAR hot	MAP HOT
MAP HOT	HOT pen	hot BAR	BAR BAR	bar map
PEN hot	day day	hot day	bar pen	MAP DAY
bar pen	bar DAY	MAP hot	HOT day	BAR map
pen PEN	map map	bar DAY	hot PEN	HOT BAR
bar MAP	DAY day	PEN PEN	hot BAR	pen DAY
HOT HOT	bar pen	bar DAY	MAP hot	HOT day
bar MAP	DAY day	PEN PEN	hot BAR	pen pen

pen hot	BAR BAR	DAY bar	MAP day	map MAP
bar bar	pen HOT	day BAR	MAP MAP	PEN pen
hot HOT	pen bar	bar day	map hot	hot hot
bar hot	HOT pen	BAR day	map map	BAR pen

Appendix B: English Visual and Auditory Word Span Task

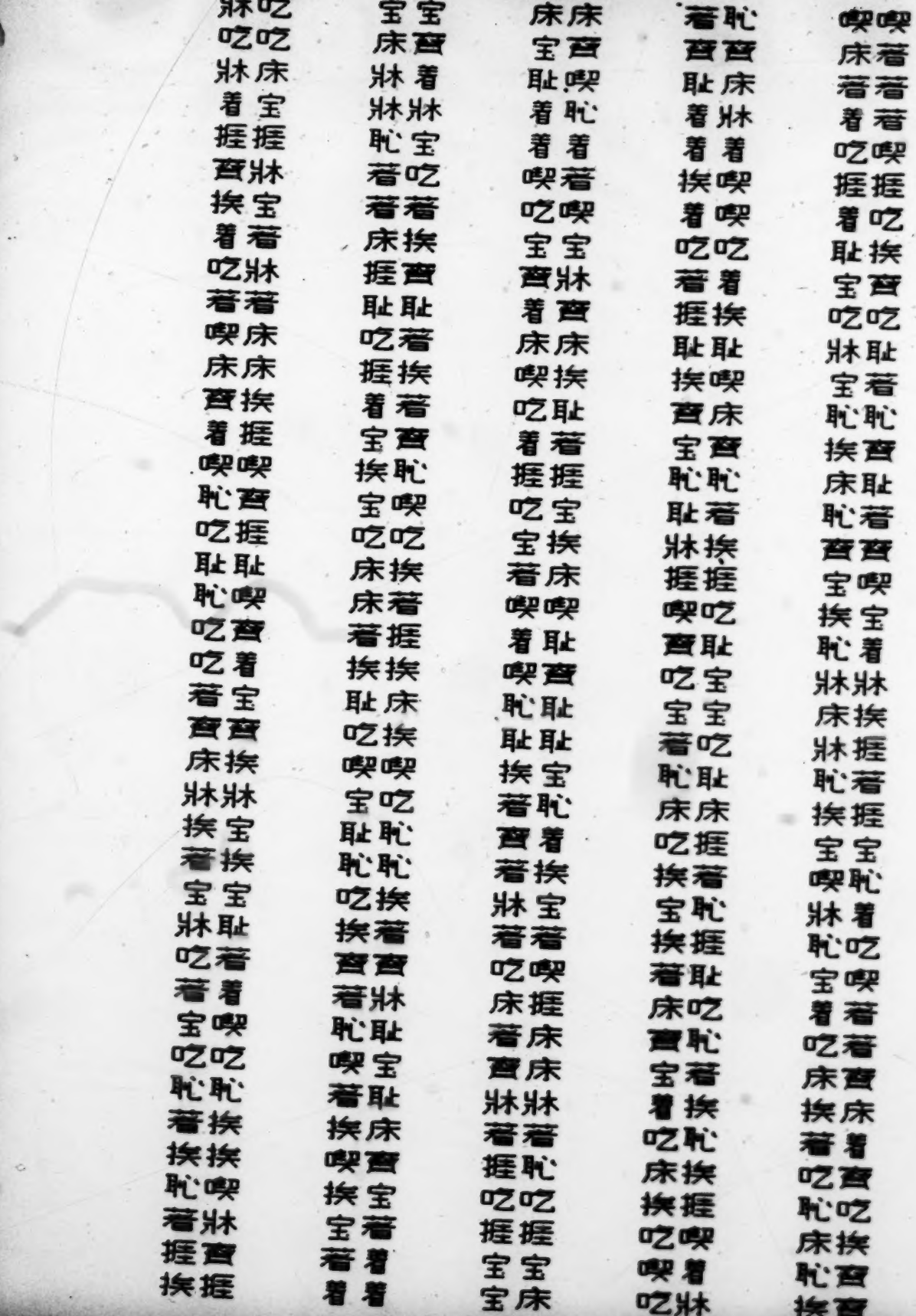
Visual Word Span Task

1. Key	Sun							
2. car	man							
3. shoe	bat	key						
4. dog	bird	book						
5. car	shoe	sun	book					
6. man	bat	key	dog					
7. man	bird	car	book	shoe				
8. bat	dog	sun	bird	key				
9. key	bat	dog	sun	bird				
10.shoe	car	bird	man	sun	bat			
11.man	kay	book	bat	sun	dog			
12.dog	man	book	key	bat	sun			
13.man	sun	book	car	bird	shoe	key		
14.book	dog	sun	bat	key	man	bird		
15.key	shoe	bird	car	book	sun	dog		
16.car	bat	key	shoe	bird	dog	man	sun	
17sun	man	car	dog	shoe	bird	key	bat	
18.sun	man	dog	bird	shoe	bat	key	car	
19.bat	key	bird	car	man	sun	shoe	book	dog
20.book	dog	man	car	sun	shoe	bird	key	bat
21.bat	shoe	key	book	car	bird	sun	dog	man

Auditory Word Span Task

1. bat	key							
2. dog	sun							
3. man	car	dog						
4. shoe	sun	book						
5. book	shoe	bat	bird					
6. key	sun	dog	man					
7. bird	car	book	man	shoe				
8. sun	bird	key	bat	dog				
9. shoe	man	book	car	bat				
10.sun	bat	dog	key	shoe	book			
11.key	man	bird	book	shoe	car			
12.book	shoe	dog	bat	sun	bird			
13.dog	sun	bat	bird	car	shoe	book		
14.bat	key	sun	man	car	dog	shoe		
15.car	shoe	book	bird	bat	sun	dog		
16.dog	car	book	shoe	bird	sun	man	key	
17.man	key	dog	bird	book	bat	shoe	sun	
18.key	man	sun	bat	shoe	book	car	dog	
19.key	sun	bat	dog	man	book	shoe	bird	car
20.car	book	bird	key	dog	man	book	shoe	bat
21.sun	key	bat	man	dog	car	bird	shoe	book

牀吃	宝宝	着床	蓄牀	喫牀
吃捱	床賣	宝賣	賣吃	床着
牀床	牀着	耻喫	耻床	着着
着宝	牀床	着恥	着牀	着着
捱挨	恥宝	着着	着床	吃床
賣牀	蓄吃	喫蓄	挨牀	喫捱
挨宝	蓄着	賣喫	着喫	着吃
着着	床挨	宝宝	吃吃	耻挨
吃牀	捱賣	賣牀	蓄恥	宝賣
宝着	耻耻	着賣	捱挨	吃着
喫床	吃蓄	床床	耻恥	牀耻
蓄床	捱吃	喫挨	挨喫	宝着
賣挨	着着	吃耻	賣床	恥恥
着捱	宝賣	着着	宝喫	挨賣
喫喫	挨恥	捱賣	恥耻	床耻
恥賣	宝喫	吃宝	耻着	恥着
吃捱	吃吃	宝挨	牀挨	賣宝
耻耻	床挨	着床	捱捱	宝喫
恥喫	床着	喫喫	喫吃	挨宝
吃賣	蓄捱	着耻	賣耻	恥着
吃着	挨挨	喫賣	吃宝	牀着
蓄宝	耻床	恥耻	宝宝	床挨
賣賣	吃挨	耻捱	蓄吃	牀捱
床挨	喫喫	挨宝	恥耻	恥着
耻牀	宝吃	着恥	床吃	挨賣
挨宝	耻賣	賣着	吃捱	宝恥
蓄挨	恥恥	蓄挨	挨蓄	喫恥
宝宝	吃挨	牀宝	宝恥	牀着
牀耻	挨蓄	蓄着	挨捱	恥吃
吃蓄	賣賣	吃喫	蓄耻	宝喫
蓄喫	蓄牀	床捱	床吃	着着
宝喫	宝耻	蓄床	賣恥	吃着
吃喫	喫宝	賣床	宝蓄	床賣
恥恥	蓄耻	牀牀	着挨	挨床
蓄挨	挨床	蓄着	吃恥	蓄吃
捱挨	喫賣	捱恥	床挨	吃賣
恥喫	挨宝	吃喫	挨捱	恥吃
蓄牀	宝蓄	牀捱	吃喫	床挨
捱賣	蓄着	宝恥	喫着	恥賣
挨捱	着喫	宝床	吃牀	挨賣



Appendix D: Chinese Memory Span Task

Visual Memory Span Task

1. 猫 山 花 日 虫 月
2. 日 狗 鸟 山 人 猫
3. 虫 月 日 人 车 花 山
4. 月 山 猫 鸟 狗 草 人
5. 山 花 日 车 鸟 猫 月
6. 鸟 人 猫 日 草 车 花 狗
7. 山 虫 花 草 人 日 狗 鸟
8. 花 人 日 草 车 山 猫 月
9. 虫 花 草 车 鸟 狗 月 日 人
10. 月 山 花 日 人 猫 虫 鸟 车
11. 山 花 日 草 车 鸟 人 猫 月
12. 虫 日 花 鸟 人 猫 月 狗 车 草
13. 山 花 日 人 猫 虫 车 鸟 狗 月
14. 虫 人 鸟 车 花 草 山 日 月 猫
15. 山 虫 花 人 日 车 草 鸟 猫 月 狗
16. 猫 月 狗 山 虫 花 草 人 日 车 鸟
17. 草 虫 人 鸟 车 狗 猫 花 月 山 日

Auditory Memory Task

1. 日 虫 月 猫 山 花
2. 鳥 山 日 狗 人 猫
3. 人 车 狗 虫 月 花 山
4. 月 山 猫 鳥 狗 草 人
5. 山 猫 月 车 鳥 花 日
6. 日 草 车 鳥 人 猫 花 狗
7. 山 猫 花 草 人 日 狗 鳥
8. 花 人 日 草 车 山 猫 月
9. 虫 花 草 车 鳥 狗 月 日 人
10. 月 山 花 日 人 猫 虫 鳥 车
11. 日 花 山 草 车 鳥 人 猫 月
12. 虫 日 花 鳥 人 猫 月 狗 车 草
13. 山 花 日 人 猫 虫 车 鳥 狗 月
14. 草 山 鳥 车 花 虫 人 日 月 猫
15. 山 虫 花 人 日 车 草 鳥 猫 月 狗
16. 人 日 车 猫 月 狗 草 山 虫 花 鳥
17. 草 虫 猫 花 车 狗 人 鳥 月 山 日